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M.J. Wojciechowski

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FOREWORD

This volume contains the proceedings of the 16th CRS Policy Discussion Seminar. The CRS seminar series brings together individuals from industry, governments, labour, universities, and other organizations to share their knowledge and views on selected issues in mineral policy.

The topic of technology policies was chosen because it is one of great urgency for the mineral sector, and also because it was felt to be a topic that is in need of far more interdisciplinary and interorganizational attention than it presently receives. The CRS seminar approach offers this variety of inputs and viewpoints.

The seminar was held at the Donald Gordon Centre for Continuing Education in Kingston on April 7-9, 1986. The program was arranged by Peter Richardson of Queen's University School of Business, in consultation with CRS. The proceedings volume was edited by Margot Wojciechowski and produced by Donna Beaubien.

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Margot J. Wojciechowski
Centre for Resource Studies

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TECHNOLOGY CHALLENGES FACING THE MINERAL INDUSTRY

Roy M. Woodbridge

The way in which you define a "challenge" will depend on your basic assumptions. Let me briefly explain my starting point and then elaborate on the nature of the challenges facing the Canadian mineral industry, and their implications. The challenge stems in a very fundamental way from the nature of technological advance itself. It also stems from the nature of changing international competition in the minerals sector. These two thrusts are linked, for the task is to use emerging technologies to help meet international competition.

If that is the technological challenge facing the mining industry, it is not unique in any sense. It is identical, in fact, to the challenge facing virtually every other sector of Canadian industry. Consequently, it is also part of a broader national challenge.

The "War" for Economic Survival

It may not be obvious to the man on the street, but Canada is at war. This is not a war involving confrontations between armies, but it is a war that will test our national resolve just as certainly as if bombs and bullets were actually involved. It is a war that demands that we mobilize our total national capabilities to fight it.

The war I am talking about is the war for international economic survival. It is a war in which technology has a strategic role to play. From the time man first invented the club, the extent of technological adaptation has always determined the relative economic performance of nations. To understand this reality in our present modern context, one has only to think fleetingly of an impoverished peasant scratching a meagre existence from the arid plains of Ethiopia. There, but for the grace of technology, and our collective ability to use it, go you and I.

In many respects then, there is nothing new in this war: it has been around for a long time. In some respects, however, the present situation is radically different from anything that preceded it. To begin with, the pace and pervasiveness of technological innovation vastly exceed anything the world has experienced in the past. The speed

of advance is being sustained, perhaps even accelerated, by the massive concentration of research expenditures in specific target areas deemed to be in the interests of individual nation states. Increasingly, the coordination and direction of these research efforts is being driven by large-scale corporate conglomerates, or within the framework of concerted national innovation programs that link industry, government, and academia in a common cause.

At the same time, technology is making the world a smaller place. As a result, it is shifting commercial advantage to companies able to produce and market on a global scale. Technology is also the determining factor in international industrial competitiveness; advanced manufacturing technologies are the driving force behind industry cost reduction and enhanced product quality efforts.

In concert with these changes, the rate at which the international community is adjusting to the application and use of new technologies is quickening. This is of fundamental importance in understanding the technology challenge facing the country, for it is becoming more difficult to stay on the leading edge of technology development and use.

Some quick examples might help to emphasize this point. In the last ten years, Brazil has established a domestic automotive assembly capability. They have developed an aerospace industry which has reached a level of sophistication where they are able to export aircraft into Canada in direct competition with our own domestic suppliers. They are now branching out into the production of computers. Ten years ago the textile industry in the Third World derived its international competitive advantage from low wages. These countries are now using, with increasing frequency and good effect, the most sophisticated electronic technologies. India, with a domestic middle class consumer society of approximately 100 million people, is exporting software. And Korea, in the space of roughly ten years, has been able to penetrate the international automotive market. The key to their success in accomplishing this seemingly impossible objective has been their rapid mastery of modern production technologies.

The implications of these trends for the Canadian mining industry are obvious: the newly industrialized countries (NICs) are going to mount a more formidable market challenge in the years ahead, in part because of their ability to use technology more effectively. The NICs are coming!

Winning the "War" in the Mining Sector

As you all know, the Canadian mining industry is already under siege from hostile international market forces. Companies have to operate in conditions of surplus global capacity and other factors that contribute to soft commodity prices. Looking down the road, there is little to suggest that these conditions will quickly alter to Canada's benefit. Consequently, the industry, and rightly so, is striving mightily to reduce costs and enhance productivity in an effort to be able to produce at prevailing prices.

Within this framework the role of technology is of primary importance. Obviously there are many ways that companies can reduce costs, but beyond a certain point there is nothing left except technological innovation. Truly, technology has to be the focus for any strategy the Canadian mining industry adopts in its struggle to retain ongoing competitive strength.

Yet the industry now finds itself in a situation not unlike that facing Germany's Luftwaffe during the Battle of Britain. You may recall that Great Britain had been slow to rearm in the 1930s, but then caught up in a rush. The result was that Germany launched its air attack on England only to discover that British aircraft technology had leapfrogged theirs and the Luftwaffe was blasted from the skies. The Canadian mining industry could very well find some Third World countries leapfrogging Canadian technological capability in the coming years, with the same effect.

Why do I say that? Well, the great majority of the production technology that will contribute to Canadian mine output over the next 10 or 15 years is already in place. In contrast, think of the technologies the NICs will be using when they open new mines five years from now.

Ask yourselves, as well, what it takes to develop technological sophistication in the application and use of new mining technologies. Is that degree of adaptation more difficult than developing a sophistication in the use of modern production technologies in the textile industry? Is that challenge more difficult than the one the Korean automotive industry successfully tackled in the last ten years?

Also ask yourself why the Canadian mining industry has any relative advantage in the ability to develop and use the next generation of mining technologies. How many skilled people does the Canadian mining industry now have who are fully familiar with the use of the new technologies? How many electronics engineers, for example, are employed within the sector?

This last is an important point, for there is a sort of religion involved in understanding the potential inherent in advanced manufacturing and industrial process technologies. It's not a religion like Christianity where enlightenment comes suddenly in the form of revelation. It is more like the addiction to a way of life implicit in Far Eastern mysticism. I draw that analogy to illustrate a gap that I have become increasingly aware of since joining the Advanced Technology Association. There is a difference in corporate culture between the mining sector and high tech companies.

I discussed this question of corporate cultures with a senior mining executive several months ago. I suggested there is a very real need for the mining industry to embrace more of the high tech corporate culture in their innovation and research activities if they are to meet the emerging technology challenge from the Third World. I was told in no uncertain terms that the Canadian mining industry is vastly more sophisticated than any Third World country in the use of technology. "We are well ahead", he said - and by implication, I suppose he meant to imply "and for evermore will remain so". Well, I think anyone who believes that is shortsighted. Any sense of comfort derived from that misconception is based in falsehood.

Technology will be the salvation of Canada's mining industry. In fact, it is the only potential salvation. However, it will not save anyone in the industry unless it is also seen as the problem.

The nature of technological advance is such that the race will not necessarily be to the swift. It will certainly not be to those who "tinker" with existing technologies and processes. The race will be to the persistent and to those able to assemble the critical mass of effort required to make quantum leaps in technological advance - and who, having once captured the lead, are able to hold it.

To win the war will require an all out, absolute, totally unrelenting commitment to technological leadership. That commitment will have to be sustained continuously through the good times and bad times alike. It will have to become so deeply ingrained in the corporate psyche that ongoing innovation is the expected norm throughout the corporation and throughout the industry. Managers who sit on top of static technology should automatically be fired, demoted or sent off on attitude readjustment courses.

What I would like to do now is to discuss the scope of the technology adjustment problem facing the mining industry. How far and in what directions does the industry's innovation effort have to go?

Elements of a "Battle Plan": Lessons from the Automotive Sector

The mining industry needs a battle plan for dealing with technological change. In this respect I would encourage you to look to the recent experience of the North American automotive sector for guidance. I believe the way they have used technology to respond to their particular set of international competitive conditions provides a model which has many lessons for the mining industry. The scale and speed of the adjustments they have had to make are in the same order of magnitude as the adjustment which the Canadian mining industry must now go through.

The original automotive assembly plant was a very simple operation in which capital, labour and materials were all assembled in one place to produce a car. That is not unlike a mine. Very little changed in that basic concept within the automotive sector until the early to mid 1970s, other than the diversification of parts sourcing and the internationalization of industry operations.

The industry was then suddenly hit with a need to respond to environmental concerns, to alter automotive technology in response to the energy crisis and to react to the sudden emergence of competition from Japan and other low-cost world producers. This combination produced rapid and major revisions in the way in which North American automotive companies develop and use new technology.

The challenge facing the industry was made more demanding by the fact that they had delayed their response to the point that they were no longer technology leaders within the international industry. They have now been running hard to catch up for 10 or 12 years and in many respects are still lagging.

It is possible to summarize their response in terms of four straightforward concepts related to the achievement of corporate business objectives. They have used technology:

- to link production levels ever more tightly to "real time" market demand;
- to respond more sensitively to changes in consumer preference (i.e. change the product);
- to enhance product quality.

In the course of introducing these changes, they have also:

- tightened corporate control over technology development.

Linking Production to "Real Time" Market Demand

The most important, and generally the least understood, of these initiatives is the move to link production more closely to real-time immediate changes in market demand.

Each North American car order is virtually a "one off" item because of the great diversity of options available. When a customer orders a car, the salesperson enters the details into the computer terminal in the sales office. The order goes out to a central processing node, where it is rerouted to the appropriate manufacturing plant, whether in Canada or the USA. An immediate signal is returned, giving a precise delivery date for the new car. At the plant, the order is exploded into a parts list which is automatically incorporated into the inventory ordering system of the assembly plant. Through increasing reliance on just-in-time deliveries, individual parts and subassemblies arrive at the plant and are strategically introduced into the assembly line. The parts are electronically coded to ensure that the right parts are built in to each specific car. At the same time, through another control system, the spare part requirements to service the car once it is delivered to the buyer are entered into the inventory ordering system in the region in which the sale was made.

In effect, the use of modern production and information technologies is moving the whole automotive production system towards real-time decision making. The fat is being removed at all stages of the chain. For the mining industry, the lessons to be derived from this use of technology are particularly relevant at the manufacturing stage.

Fifteen years ago the automotive industry planned production on the basis of yearly production levels, which were then broken out into monthly and perhaps weekly or even daily production targets. That is not dissimilar to the manner in which mining industry production targets are now set. However, the automotive industry has evolved to the point where daily production targets are increasingly tied to last week's orders.

What this model suggests for the mining industry is that more effective efforts must be made to link production decisions at the mine face directly to real-time market demand for mineral commodities. The mining industry now functions in real time at the marketing end of its operations. As you move towards the mine mouth, the time lags and the associated overhead costs become more pronounced.

I fully recognize that bulk production differs radically from the diversified automotive assembly process. The mining industry is also capital intensive and production must

fit within a limited range of production options in order to allow the equipment to be utilized on an economic basis. Thus, tying the mine to the market is an extremely difficult challenge.

Nevertheless, let me suggest to you that the industry must attempt to do just that. There are significant cost savings to be derived. To do this will require fine tuning the pipeline. That, in turn, means automating underground production and then linking production decisions more intimately into total corporate planning systems that are highly responsive to short-term market signals.

Responding to Consumer Preferences

The second area of technology development I would like to explore is the manner in which the automotive industry uses technology to help it respond more effectively to changing patterns of market demand. There are many ways in which the automotive industry responds to customer wishes, but their use of technology has enabled the industry to be significantly more market driven than at any time in the past.

If we go back to the original sales order, it goes to the central node and is distributed to the appropriate factory and so forth. That order also goes to the central sales organization where information on regional sales is consolidated on a daily basis and short-run decisions are made with respect to the reallocation of advertising and promotional campaigns.

The same information is passed to the market development group which consolidates trends in consumer preference for eventual use by the design groups within the company in deciding on the nature of new product offerings. A complementary thrust is the emphasis on improved product quality, which I will have more to say about shortly.

The lessons to be derived from the automotive industry's shift towards greater customer responsiveness are, perhaps, more applicable to the materials end of the mining chain rather than the exploration or primary production stages.

A recent survey by the CMA indicated that the manufacturing industry's highest priority for research and development activity is in the materials area. The scope of coming innovations in this field is such that many mining companies may find they are forced to make a basic decision as to whether they are mining companies or suppliers of industrial materials. That distinction is important. It obviously will have an impact on the overall thrust of the

industry's R&D activities, the level of expenditures, the targets selected and the manner in which the research is organized and conducted.

Materials research is a difficult area for the mineral industry to address. Canada currently produces over 60 mineral commodities; research with respect to materials use, to the extent that it currently exists within the country, tends to take place on a commodity-specific basis. It is not clear that this is the most appropriate way to organize an industry response to changes in materials demand.

If materials research is conducted on a commodity-specific basis in order to protect market share, it simply accentuates the competition that already exists between commodities. In effect, it is an attempt to force-fit market demand to correspond to the availability of primary resources. It is not, as in the case of the automotive industry, a legitimate effort to respond sensitively to emerging trends in consumer preferences or expectations.

From a company point of view, or from the point of view of specific commodity sectors, the current approach is logical. But from a national perspective it is not at all clear that we can afford to fragment our very limited research capability by encouraging this kind of inter-commodity competition. How does Canada as a whole gain if corporate research simply means that aluminum replaces copper or a zinc-coated alloy replaces aluminum, only to find that some exotic high strength plastic weakens the market position of all of these commodities?

As well, can we afford to fragment our national effort in emerging advanced material areas? Does it really make sense for Alcan and Cominco to compete for the fledgling gallium arsenide market? Is the scale of research and product development effort required to capture world markets for exotic new materials such that we have to pool our total national resource to be successful?

I don't know the answer to these questions. Nor do I have the answers to how we might organize on a national basis to accomplish this type of cooperative initiative. There is a need, perhaps, for a national strategy on advanced materials to sort this out.

However, it is worth pointing out that we are dealing here with the most competitive end of the industry. My experience with the marketing arms of mining companies is that they are the most secretive groups within the country. They make our security service look positively transparent. That type of secrecy may be appropriate at the sales end of the business, but at the product development or market research phase there does appear to be scope for greater intercorporate cooperation.

The marketing people within the mining industry talk about it being relatively easy to track commodity trends. That may be, but who is doing it? Where is the pool of national knowledge on emerging patterns of commodity demand? More importantly, how long will it take Canada's mining industry to respond to emerging market opportunities for the production of new materials? And how, and by whom, is the growing body of knowledge on these potential opportunities now being assembled in Canada? Are we now structured to facilitate the transition from awareness to the actual production of new materials?

I would suggest that, if the automotive industry example has validity in the minerals sector, then Canada's mining companies have to tie their research and product development activities more closely to emerging patterns of materials demand (as contrasted with commodity forecasts). To do that effectively there appears to be a need for more cooperative market research on trends in materials use that is geared towards downstream investment in advanced materials.

Improving Product Quality

The automotive industry is using technology to enhance product quality and reliability. They are doing this in two ways. First, by emphasizing the development and introduction of advanced manufacturing processes in their assembly operations. In this respect, there is obviously a need to tailor production technologies to the specific requirements of producing the next generation of automobiles. Thus, in a roundabout way, the research priorities related to process innovation are again tied directly to market demand.

The second thrust on quality control is through parts suppliers. On-line process or quality control equipment is becoming a contractual requirement that the automotive companies are imposing on their parts suppliers. Similarly, the ability of the parts suppliers to interact at a scientific and engineering level with automobile design groups is an increasingly important element in their ability to negotiate long-term supply contracts.

The implications of this quality push are rolling steadily down through the entire industrial chain to the primary commodity producers. In very simple terms, the binding requirement on the parts suppliers - and on the manufacturing industry in total - to meet increasingly stringent quality standards means they are placing a premium on buying only the highest quality mineral materials.

Thus, the use of technology to enhance the quality of the products supplied by the mineral industry is rapidly becoming a priority requirement.

Controlling Technology Development

The final theme I would like to discuss is the manner in which the North American automotive industry has steadily exerted a greater degree of control over the development of the technologies on which their survival depends.

As I have already indicated, automotive companies are exerting a strong influence over the technologies being used by their parts suppliers and are increasingly linking the contracting of parts supply to the ability of individual companies to interact at a scientific and technical level with automotive designers. This process is evolving towards even higher levels of integration in initiatives such as General Motors Saturn Project, in which all parts suppliers will have to be located within a 300-mile radius of the assembly plant.

The other side of the equation is the manner in which the automotive industry is exerting tighter control over the development of their own production technologies. They are doing this by forward integration into advanced technology companies that are on the absolute front end of development in the emerging technology fields that will determine the next generation of automated production equipment. General Motors' involvement with Diffracto, a Canadian company that has a world-leading position in the area of machine vision, is an example.

These directions of change in the area of technology development contrast sharply with the current situation in the mining sector.

For a very long period of time, Canada's mining industry has delegated much of the responsibility for technology development to arm's-length suppliers within the international community. In recent years, as the technology imperative has become more visible, this situation has begun to change. For example, Inco's major technology development initiative that underpinned their shift to bulk mining led to the establishment last year of their Continuous Mining Company. Noranda, through their venture capital arm, has integrated forward into a number of advanced technology companies, although more for commercial than technology related reasons. The agreement of four of Canada's major mining companies to establish the Hard Rock Mining Corporation, is indicative of a growing willingness of mining companies to cooperate on technology development.

However, while these indications of change appear to be moving in the right direction, the industry as a whole still has a long way to go. Its total research and technological innovation activity is still extremely limited in absolute terms. The research focus is scattered. There is considerable overlap in research activity between companies, and the mechanisms for translating the results of successful process research into products that can be produced and then marketed in Canada and world wide are limited.

While General Motors can take control over their own technological destiny, it is highly doubtful that individual Canadian mining companies can. In 1985, General Motors' annual sales world wide were $96.5 billion; their level of capital investment exceeded $15 billion. In contrast, Canada's cash-poor mining industry, with total sales of approximately $17 billion, is reported to spend less than 1 percent of these revenues on R&D and market research combined. Few companies within the industry actually do any research. The great majority of those that do, spend a high proportion of their research funds on environmental quality improvement, and on basic tinkering with production bottlenecks using established technology.

The hard reality is that individual companies will not be able to bring about the required level of technological innovation on their own. Some form of broadly-based cooperative initiative appears to be essential if Canada's mining industry is to take control over the development of the technologies that will determine their ability to survive in the future.

Cooperation Wins Wars

Let me, in summary, reiterate some of the points I made at the beginning of this talk. First of all, I said that Canada is in a war for international economic survival. This is a war in which technology plays a strategic role. The pace of innovation is quickening. The rest of the world is adjusting rapidly to the use of new technologies and is increasingly using technology as a strategic tool for promoting national economic growth.

Thus, technology is not Canada's salvation, it is part of our national challenge.

To meet this challenge, a strong commitment to technology leadership must become part of the corporate psyche. This will require a significant level of industry effort. Because the challenge exceeds the capacity of individual companies to address it, success hinges on our

ability to mount a national effort. The commitment to technology leadership must, therefore, also become part of the national psyche.

Meeting the specific technology challenge facing the Canadian mining industry will require a broad, total industry effort backed by government and supported by every available resource within the country. For example:

- we have to get mining engineers out of their own stopes and into broader dialogue within their industry;

- the mining industry as a whole has to tap all available expertise in other industrial sectors;

- the focus of government research has to be reoriented from the assessment of trends in technology use to helping solve immediate industry problems;

- university researchers have to refocus their efforts from asking "what" to answering "how".

In fairness, some progress is being made on all these fronts. However, the pace of change must be accelerated.

Since I have raised the question of "how", let me leave you with a rough concept for organizing this kind of effort.

First, it is important to recognize that it is a national problem requiring a coordinated, national solution. Some people may have to give up some of their existing prerogatives in order to contribute most effectively. We cannot afford to fragment our effort by dividing our limited resources between competing provincial initiatives or between the federal government and the provinces. There has to be a single coordinated push.

Second, the initiative must be industry driven. Unless Canada's mining companies are prepared to join together in a common research and technology development thrust, there is little hope for deriving anything approaching a Canadian made solution.

Finally, because industry cooperation is essential, the program cannot be led by a single company. That leaves the Mining Association of Canada as a potential coordinating body.

The model I would urge would be a version of the research program run by the Australian Mining Association. This agency targets research on priorities established by industry and then seeks funding from companies who share those specific concerns. I believe it is important, given the scale and urgency of the task, to go beyond the

Australian model by linking government research and university efforts within the framework of the research priorities established through such a program.

I throw that idea out, not because I feel it is definitive, but simply to give the discussion in the next two days some focus. We have a problem. We need a new mechanism for dealing with it.

In this war for economic survival, it is important that we adopt a "them" versus "us" mentality. We are going to be severely tested in the coming years as a nation. You are going to be tested as never before as an industrial sector. If we fail to respond effectively, it will only be because we lack the wit and intelligence to mobilize our full resources in anticipation of the battles that loom.

Unfortunately, I believe there is a very real risk of this happening. And if we fail, we will wake up some morning not too long removed from today and discover, as Pogo did when he went out looking for the real enemy, that "it is us".

REALIZING THE OPPORTUNITIES

Margot J. Wojciechowski

Introduction

In considering ways to realize the opportunities offered by technological innovation, this presentation will look at the issue from four different aspects:

- the timeliness of the present focus of attention on innovation;
- the interdisciplinary nature of the innovation process;
- the level and focus of present innovation efforts;
- recommendations to improve the rate of innovation in the Canadian mineral sector.

Timeliness will be considered first from a rather philosophical perspective, and then in a more practical vein. We will also look at the absolute necessity for cooperation among diverse groups and disciplines, if the potential for innovation is to be realized. Next, we will look at some of the particular areas of concern within the technological innovation process, as it exists at present, including the present level of effort, the present focus of efforts, and a variety of economic, organizational, and other factors that inhibit the effectiveness of the innovation effort within the mineral industry.

Finally, the recommendations that were developed in the course of the CRS study commissioned by the Ministry of State for Science and Technology (MOSST) and Energy, Mines and Resources Canada (EMR) will be outlined.[1] Although their principal focus is government activities in support of innovation, the recommendations can be more broadly applied to industry, university, and other organizations, as well as to governments.

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1. M.J. Wojciechowski and P.R. Richardson, "Opportunities for Technological Innovation in the Canadian Mineral Industry", draft report submitted 7 March 1986 to the Ministry of State for Science and Technology.

Timeliness

From The Perspective of Economic History

Economic historians have identified long-wave cycles in economic activities. Although they lack credibility as forecasting tools, these cycles can lead one to stand back from day-to-day concerns and consider a broader perspective. Probably the best known work in this area is that of Kondratieff, who identified 3 waves of 45- to 60-year cycles of growth and decline in economic activities between the industrial revolution in the 18th century and the 1920s. His theories lost popularity after World War II; the lessons of past recessions were forgotten, and the rapid rate of economic growth of the 1950s and 1960s came to be viewed as the norm, expected to continue more or less unabated. However, signs of recession in the late 1960s led to renewed interest in long-wave cycles, and subsequent work in the 1970s confirmed Kondratieff's earlier observations, and expanded upon them.

Van Duijn's version of the long-wave cycles is shown in table 1. If history were to repeat itself, we might expect the current hard times to turn to recovery in the very near future. Unfortunately, economics is more noted for its wisdom in hindsight than as a reliable means of prediction. There is no reason to assume that the patterns will repeat themselves identically; there are too many intervening variables at work.

Table 1

VAN DUIJN'S LONG-WAVE CYCLES

	Prosperity	Recession	Depression	Recovery
1st wave	1783-1803	1815-1826	1826-1837	1837-1847
2nd wave	1847-1866	1866-1875	1875-1884	1884-1893
3rd wave	1893-1913	1921-1929	1929-1938	1938-1949
4th wave	1949-1967	1967-1975	?	?

Source: S.W. Erickson, "The Transition Between Eras: the Long-Wave Cycle", Futurist, August 1985.

However, another line of study sheds some interesting light, as well as hope on the prospects for recovery. Researchers have determined that, while the pace of inven-

tion, the generation of new ideas and concepts, is fairly steady, the pace of innovation is not. It is in fact closely but inversely correlated to these long-wave cycles.[2] An obvious deduction is that the period of depression triggers a renewed interest in the innovation process, which in turn provides the impetus for the recovery. Since we now appear to be at or near the bottom of a long-term cycle, the present emphasis on technological innovation is no accident: it is both a a result of the decline and the means to reverse it.

Let us suppose we are in fact on the verge of the recovery phase. The mining industry will be carried along, lagging a bit perhaps, but nevertheless benefiting from the upturn and from the renewed interest in innovation. Our unused mineral production capacity and low-cost position will give us a good start. But does this automatically mean that the Canadian mineral industry will be able to maintain its strong access to the export markets that are so essential to us? Not necessarily. There are some very effective competitors out there, and some potential ones like China that have not even begun to show what they can do.

From the Perspective of Comparative Advantage

Let us now leave the area of speculation and look at some practical questions of comparative advantage. In 1981, EMR evaluated factors affecting the competitive position of the Canadian mineral industry, relative to producers in other jurisdictions. This list, published in the early draft of EMR's "Mineral Policy: A Discussion Paper", was reevaluated by Noranda, and both versions are given in table 2. The conclusions are fairly negative, and in fact even these 1981 evaluations have since proven to be optimistic with respect to three of the four factors identified as positive:

- type of ore (co- and by-product metals are no longer the salvation they once were);
- energy costs (falling oil prices have undermined Canada's advantages of low-cost energy);
- exchange rates (except with respect to the USA).

It should be noted that these evaluations apply to the industry in total, not to any one deposit.

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2. S.W. Erickson, "The Transition Between Eras".

Table 2

IMPACT OF MAJOR FACTORS AFFECTING THE COMPETITIVE POSITION OF THE CANADIAN MINERAL INDUSTRY IN THE 1980s

Factors	EMR	Noranda
Ore grade	Slightly negative	Slightly negative
Type of ore	Strongly positive	Positive
Location	Moderately negative	Moderately negative
Capital costs	Slightly negative	Slightly negative
Labour costs	Strongly negative	Strongly negative
Energy costs	Strongly positive	Positive
Exchange rate	Strongly positive	Strongly positive
Taxation	No change anticipated	Moderately negative
Technology	Strongly positive	Strongly positive
Environment	Slightly negative	Strongly negative
Tariffs and trade barriers	No change anticipated	Slightly negative

Source: Noranda Mines Ltd., "Comments on Mineral Policy Review", unpublished, July 1981.

The only positive factor left, it would appear, is technology. But hanging on to that advantage will not be easy, in all phases of mineral production. Evidence suggests that we are losing ground in our leadership in exploration technology, especially geophysics, as competitor nations are heavily subsidizing the development of new geophysical instrumentation and techniques. Since Canada has virtually no indigenous mining equipment industry, mining equipment innovations arise mainly outside of Canada, although major advances are being made here in bulk mining methods. In extractive metallurgy we have strengths, but face serious competition from companies such as Mitsubishi and Outokumpu with much larger budgets for R&D and for marketing. Relatively little work has been done here on new product development and new materials.

It seems clear therefore that the current emphasis on technology is timely, in terms of both the place of the mineral industry in the overall economic picture, and in terms of the competitive position of Canadian producers in international mineral markets. What is needed to make the technology push effective?

Interdisciplinary Needs

Roy Woodbridge has stressed the necessity for cooperative efforts and interdisciplinary work in innovation in his presentation. Let us look at some additional arguments in support of this contention.

The technologies that will drive the economic recovery, whenever it comes, will in all probability be the high tech technologies that were discussed last night, plus others such as biotechnology and physics. These are not the core technologies (shown in bold type in figure 1) of the mining industry, the technologies which are most likely to arise inside the industry. However, these new technologies will have to be drawn upon by the industry, if it is to achieve technological breakthroughs of major proportions. This will require broader technical skills within companies, as well as cooperative ventures, and forward integration into firms that can provide (or that may in future provide) needed technologies.

Figure 2 shows us three types of technology evolution curves. T_1 curves represent incremental change, now the dominant sort of technology change in the industry, including, for example, better drill bits, bigger trucks, or more selective reagents. T_1 changes generally arise directly from improvements to existing operations; they rarely involve R&D, and they present little risk.

T_2 curves represent major changes in existing technologies, such as the introduction of flash smelting for copper. They include new combinations of existing technologies, as in process control innovation. They are likely to be associated with expansions or with new plants, involve some risk, and generally are the result of R&D within the industry.

T_3 curves result from major breakthroughs, and almost always require inputs from outside the industry. The changes tend to revolutionize the industry, and may make existing plants and processes obsolete. A striking early example for mining is the introduction of the steam engine. A more recent example can be found in the steel industry, with the introduction of new processing and casting methods and smaller and more flexible plants. T_3 innovations offer the greatest risk, both technical and market, but also by far the greatest rewards.

I am sure that Alcan and Inco can confirm that major efforts directed at type 2 and type 3 innovations require the cooperation of a great many different kinds of organizations and a broad range of disciplines. Unfortunately, in the present mineral industry R&D programs in Canada,

ROBOTICS	EXPLOSIVES	PROCESS CONTROL
MATERIALS HANDLING	MINING ROCK MECHANICS	CONSTRUCTION MATERIALS
MICROBIOLOGY	COMMUNICATIONS	ELECTRICAL EQUIPMENT

ROBOTICS	INSTRUMENTATION	PROCESS CONTROL
MATERIALS HANDLING	PYROMETALLURGY HYDROMETALLURGY	MICROBIOLOGY
CONSTRUCTION MATERIALS	COMBUSTION	REFRACTORIES

Figure 1. Core and Peripheral Technologies

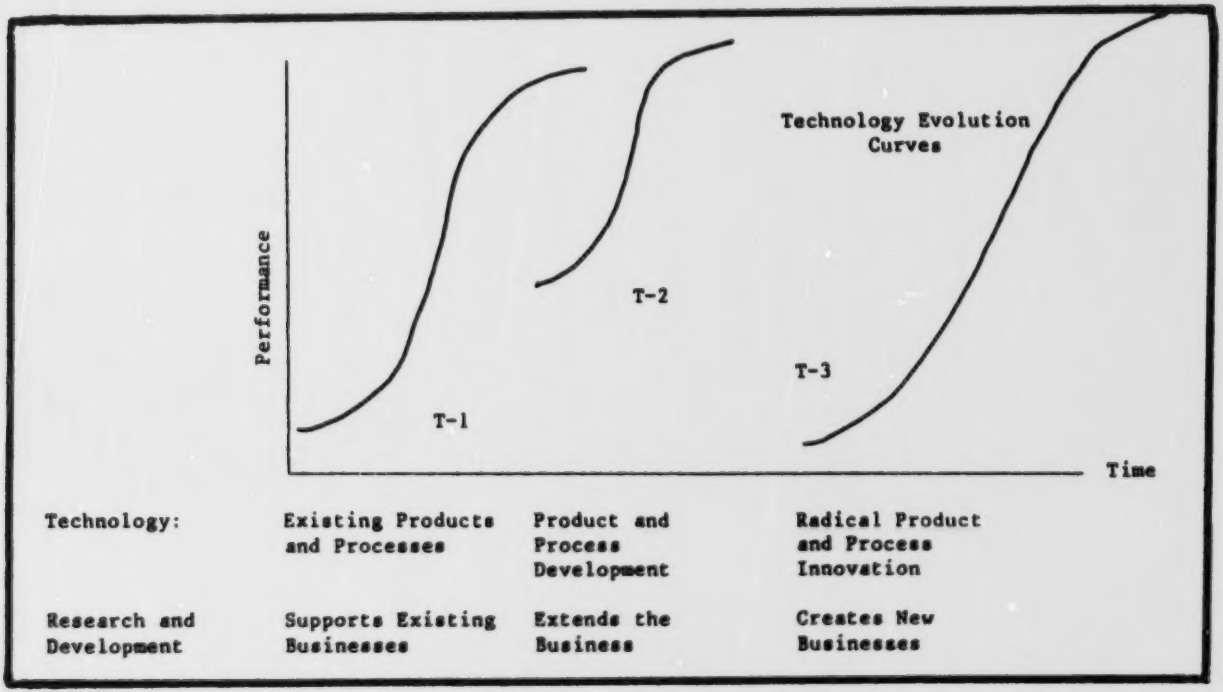

Figure 2. Technology Evolution Curves

whether in companies, universities, or government laboratories, this sort of broadly-based team effort is the exception rather than the rule. This gathering today represents many of the areas of technical expertise outside of mining per se that can contribute to innovation success in the industry. I hope there will be opportunities throughout the seminar, and beyond it, to explore some of the means for cooperation.

Realizing the Opportunities - Areas of Concern to be Overcome

The opportunities for technological innovation in the mineral sector far outdistance the capabilities of the resources, both human and financial, presently allocated to R&D and technology innovation. The shortfall in resources is aggravated by serious problems in the focus and the effectiveness of the present efforts. This section will look at some of the obstacles that lie in the way of realizing the opportunities for innovation, with a view, first, to drawing them to your attention, and then to calling for discussion on how they might best be overcome.

1. Level of R&D Activities

The level of funding for R&D activities (over all economic sectors, not just mining) is low in Canada, relative to that in other industrialized countries, as shown in table 3. While R&D is only the first stage of the innovation process, and is in fact much less expensive than the demonstration and commercialization stages, the R&D funding levels indicate the degree of interest and commitment to technology and innovation, as well as the capacity to handle it. Figures on expenditures for the later stages of innovation are less easy to come by, and in fact some are hopelessly mixed in with the R&D figures. Nevertheless, the evidence suggests that, with a few notable exceptions, both government and industry lag in these areas in Canada as well.

For minerals, the generally low level of funding for R&D in Canada is aggravated by the fact that the sector falls far behind many others in terms of financial commitment. Data supporting this finding are more readily available for the USA, where National Science Foundation figures (table 4) show nonferrous metals to have a very low level of R&D intensity, although other resource sectors were even lower. The comparable figure for Canadian mining companies in 1983 was 0.6 percent (see table 5).

Table 3

INTERNATIONAL COMPARISON OF R&D EXPENDITURES,[a] 1975 and 1981

	R&D Expenditures as Percent of Domestic Product of Industry		
	1967	1975	1981
Sweden	1.3	1.6	2.3
W. Germany	1.3	1.6	2.2
USA	2.4	1.8	2.0
Japan	0.9	1.3	1.6
France	1.4	1.4	1.5
Canada	0.7	0.6	0.8

Source: Statistics Canada, Industrial R&D Statistics 1983, Cat. 88-202, 1984.

[a] For the entire economy, not just mining.

Table 4

R&D INTENSITY[a] IN SELECTED U.S. INDUSTRIES

	1960	1970	1981
Aircraft and parts	22.5	16.2	15.3
Electrical equipment	11.2	7.3	6.8
Machinery	4.7	4.0	5.2
Chemicals	4.5	3.9	3.8
Fabricated metal products	1.3	1.2	1.4
Nonferrous metals	1.0	1.0	1.2
Paper and products	0.7	0.9	1.1
Lumber and wood products	0.6	0.8	0.9
Ferrous metals	0.6	0.7	0.8

Source: National Science Foundation, quoted in P.E. Queneau, Materials and Society, 9,2 1985.

[a] total funding as a percent of net sales.

The two Canadian mineral companies, Alcan and Inco, that have shown the foresight to dedicate significant resources to R&D have reaped great benefits. Alcan has defended its market share with aggressive R&D in product innovation, and Inco has made outstanding productivity improvements with its bulk mining innovations. In 1984 Alcan's R&D expenditures were about 1.2 percent of net sales, and Inco's were 1.5 percent.

Given current financial constraints on companies and on governments, it is unlikely that major increases in R&D funding for the mineral industry as a whole can be expected in the short term. Nevertheless, there is much that can be done to increase the impact of present funding levels by improving the focus and effectiveness of existing programs.

2. Focus of R&D and Innovation Activities

There are two dimensions to the issue of focus of effort as a barrier to realizing technological opportunities:

- the first relates to the distribution of R&D and innovation programs among the various stages of mineral production;

- the second relates to the innovation process itself, as it moves from basic theories through R&D to demonstration and ultimately, but crucially, to commercialization.

2a. Stage of Production

While mining contributes almost 50 percent of the value of mineral production (vs. 16 percent for smelting and refining and 35 percent for primary metals), less than 30 percent of the mineral sector R&D expenditures go to the mining stage (see tables 5 and 6).

For a number of reasons, the relative neglect of R&D in the mining sector seems to be very shortsighted. This is not to suggest that too much time and effort is going into metallurgy, but rather that other activities, particularly mining, are missing the boat. In fact, the emphasis on R&D in metallurgy is a major reason for the relatively strong competitive position of the smelting and refining sector, and presents a strong argument for more effective R&D in other aspects of the industry. The relative in-

Table 5

R&D EXPENDITURES* WITHIN CANADIAN MINERAL COMPANIES, 1983

	Expenditures ($ million)	As Percent of Sales	Percent of Total
Mining	41	0.6	28.7
Primary metals (nonferrous)	81	1.3	56.6
Primary metals (ferrous)	21	0.3	14.7
Total R&D expenditures	143		100.0

Source: Statistics Canada, 88-202.

* including government support.

Table 6

CANMET[a] PROPOSED EXPENDITURES FOR MINING AND METALS, 1985/86

	Expenditures ($ million)	Percent of Total
Mining	5.5	14.0
Coal mining and preparation	6.0	15.2
Mineral processing	17.7	44.9
Metals and materials	10.2	25.9
Total mining and metals	39.4	100.0

[a] CANMET is the federal government's R&D organization for the mineral sector, and in addition has been the principal source of funding for industry and university R&D in minerals.

adequacy of the R&D effort in mining, in terms of needs and opportunities, becomes more apparent when considering, for example, that the mining stage in Canada:

- produces almost 50 percent of the value of production;
- incurs over 50 percent of the costs of mineral production;
- produces concentrate, about 50 percent of which is exported as is, without further processing in Canada;

- incurs the highest proportion of metal losses over the production cycle;
- has the highest inefficiencies of any production stage;
- is capital, labour, and technology intensive;
- has 280 producing mines, each of which may generate unique R&D and innovation needs;
- has a slower rate of technology transfer than metallurgy;
- has a weaker competitive position in the world than the metallurgical sector;
- is more likely than the metallurgical sector to see new developments in the near future which could exploit radically new technology.

Furthermore, the ability to mine ore that is presently uneconomic would extend the life of many mines in Canada, effectively creating new resources and reversing the trend towards high-grading.

It appears that, while the level of R&D and technology effort in metallurgy is not excessive or even adequate to exploit all of the potential opportunities, the present focus fails to take advantage of one of the areas of greatest need and opportunity, which seem to lie in mining techniques and equipment.

Other areas of growing neglect are R&D in basic earth sciences and mineral exploration, and in mineral processing, particularly hydrometallurgy. New product development is receiving increased attention, but much more needs to be done here as well.

2b. Stage of the Innovation Process

The second dimension of focus is the stage of the innovation process. Risk is encountered throughout the innovation process, in commercialization just as in the early stages of R&D. Furthermore, costs in most cases increase sharply as the innovative process moves out of the laboratory into the pilot plant or prototype demonstration phase. Nevertheless, government support and industry activities concentrate on the earlier stages of R&D, with very little effort in equipment development and demonstration or in commercialization. There are no formal government programs whatsoever for following innovative ideas through from conception to commercialization, although a few ad hoc projects, such as the airborne gradiometer, and Lovatt's tunnel-boring machine, testify to the effectiveness of such follow-through.

Industry spends much less than it should on the later stages of innovation, the commercialization and marketing stages, both for mining and process equipment and for mineral products. Bill Deeks of Noranda Sales was only partly facetious when he suggested at the productivity seminar here last year that the spending proportion should be $1 for exploration, $10 for R&D, and $100 for marketing. In fact, the emphasis goes in the opposite direction. The result is ineffective use of the resources that have been allocated to the earlier stages, no matter how successful the R&D may be.

3. Economic Constraints in the Industry

The Canadian mineral industry is presently suffering severe and sustained reductions in cash flows. The industry's response has been spectacular, as it has saved itself from near extinction in recent years. Unfortunately, the rationalization steps have generally included reductions rather than increases in spending on technology. Furthermore, the decrease in the number of new mineral developments means a reduction in the number of opportunities for implementing new breakthrough technologies. Adding to the problem are the cuts in R&D staff and the virtual freeze on hiring since 1981 (except for the gold sector), which have reduced the flow of new people and new ideas into firms, and represent a serious long-term problem for the industry.

4. Negative Attitudes Towards Innovation

Risk aversion and the "blinker syndrome" reduce the commercial potential of successful research and development, block technology transfer, and add to the costs and the inefficiencies. Technical risk aversion exists at all levels in most mining companies, as well as in government funding agencies. The "blinker syndrome" exists within and among companies, universities and government departments, and is accentuated by the intellectual and physical isolation that exists in Canada. It resembles the "not-invented-here" (NIH) syndrome, but is more deeply rooted in the compartmentalization that arises from academic discipline and the organizational structure of universities and companies.

5. Isolation of Industry R&D Activities

With a few notable exceptions, company R&D and technology programs are small and conducted in-house, in isolation from many potential sources of assistance which might help to stimulate innovation, such as other companies' R&D teams, suppliers, consultants, universities, and government research facilities and technology centres. They are typically aimed at T_1-type incremental innovations for company-specific processes and equipment. Very few companies possess the critical mass of scientists and engineers necessary to maintain a significant research and development effort. The isolation is fostered in part by the geographical dispersion of the industry, and worsened by the tendency towards secrecy among many establishments.

In these organizations, research and development has neither the mandate nor the resources for the long-run effort needed to rework traditional methods and equipment or adapt new technologies. With the exception of recent initiatives in the asbestos, coal, and potash industries, and through HDRK, MIROC and NIDI, there are very few joint ventures between companies, and too few with institutions such as universities. Neither is there an industry-wide research organization similar to AMIRA in Australia or the Chamber of Mines in South Africa; these organizations, controlled by industry, have proven to be effective in focusing, coordinating and evaluating research and development, innovation, and technology transfer.

The Mining Association of Canada (MAC) has made modest steps towards a technology focus, through publications, meetings, and its cooperation with the Canadian Advanced Technology Association, and the Canadian Institute of Mining and Metallurgy (CIM) offers a forum for exchange of ideas and R&D results, but publishes only a fraction of the resulting papers. Unfortunately, these efforts are still a long way from providing hands-on industry-wide cooperative research efforts in areas of common interest.

6. Lack of An Indigenous Equipment Industry

The lack of a Canadian-owned mining equipment industry appears to be, at least in part, the result of a deliberate decision on the part of Canadian mining firms to stay out of the equipment business. However, mining companies need to work closely with equipment suppliers, especially at the later stages of design and demonstration. In Canada, this opportunity is often unavailable, as the equipment industry

is dominated by foreign-owned equipment companies which usually do their technical development elsewhere, except for minor modifications. Where Canadian mining companies do establish technical linkages with foreign firms to develop new equipment, potential benefits from the future sale of this technology are usually lost to Canada.

Canadian-owned equipment suppliers tend to be small and poorly funded, with limited innovation capabilities. The recent capital spending cutbacks by the mining industry has hit these firms particularly hard. Even Jarvis Clarke, formerly the largest Canadian-owned mining equipment manufacturer but now foreign-owned, has been forced to reduce its engineering and design staff.

7. The Government Policy Process

Governments are presently handicapped in establishing research and development policies for the mineral sector by a number of factors, some of which are unavoidable and some of which can be remedied. Among the unavoidable factors are such political necessities as:

- the need to treat various economic sectors in an equitable manner;
- the need to encourage economic activity and employment in depressed regions and communities;
- the need for exports to meet the pressures of the balance of payments accounts;
- the need to avoid the appearance or practice of subsidizing an export industry;
- concerns for environmental and health and safety issues.

Among the correctable factors that are counterproductive in establishing science and technology priorities are:

- the proliferation of departments involved in this area, and the resulting conflicts, gaps, and overlaps in policies and programs;

- inadequate information in government departments about the industry's current performance in such areas as R&D activities, profits, productivity, and comparative advantage;

- inadequate information on price and market trends and forecasts;

- lack of technical expertise at the senior levels of policy analysis and decision making;[3]

- insufficient use of rigorous and systematic analyses of the potential economic and social impact of policy changes, such as specific technical breakthroughs that can be anticipated;[4]

- by contrast, a failure to stand back and identify key areas of need and opportunity (although several efforts in this direction have been undertaken in recent years);

- the short-term orientation of political decisions, in contrast with the long lead-times required to carry innovations through from conception to demonstration and subsequent commercialization;

- reluctance of the government to share the risks of technical innovation (especially demonstration and commercialization) with the private sector, or to accept the inevitability of occasional failures.

8. The Administration of Government Technology Programs

Additional major barriers to innovation are created by the structures and processes in place for allocating funds and for directing and evaluating federally-funded research and development. The structures are essentially all in-house government bodies. Once the overall level and distribution of funding has been established at the Cabinet committee level, these line departments and agencies are in control of resource allocation within their area of operation, under Treasury Board guidelines.

Allocation decisions are made and priorities are established by bureaucrats, who may consult with, but who are not accountable to, university and industry advisors. Nor

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3. See, for example: M.J. Wojciechowski, ed., Mineral Policy Formulation: the Role of Scientific and Technical Knowledge, Centre for Resource Studies, 1982.
4. See, for example: Wassily Leontief, "The Choice of Technology", Scientific American, vol. 252, no. 6, June 1985, pp. 37-45.

are these individuals subject to the same economic pressures or practical demands imposed on industry decision makers, who must make decisions in the face of wild fluctuations in cash flows, discontinuities in the quality and nature of ore reserves, changes in demand, competition from other suppliers, and an inexorable "bottom line". (In the short term, this insulation should be an advantage for R&D programs.)

8a. In-House R&D

Federal in-house R&D essentially means CANMET plus some GSC activities. Excellent work is done in these two organizations, in spite of some severe institutional handicaps, particularly:

- the regulations of the Public Service Commission, which are geared to career protection and progression, and are often too inflexible for an R&D organization, where flexibility is a major essential;

- the regulations of the Treasury Board, which are designed to exercise care over expenditures, and can come into conflict with the high-risk nature of R&D expenditure goals.

Advisory committees provide input from industry and university representatives, with increasing effectiveness in recent years, particularly in the case of CANMET's National Advisory Committee on Mining and Metallurgical Research (NACMMR), and its network of subcommittees. However, advisory committees can only advise, and policy and administrative decisions continue to be made in-house, influenced by a variety of political and institutional factors that frequently have little or no connection with R&D and innovation goals.

8b. Contracts

The contracting-out system for mineral-related R&D, largely arising in CANMET, suffers from similar problems, and some additional ones of its own. Priorities and funding allocations are established in-house, as are contracts' criteria and methods of evaluation. The criteria and methods are apparently designed primarily to reduce risk and prevent funding abuses, rather than to encourage creativity and permit the

exercise of peer judgement in evaluation of the quality and usefulness of the results. Contracts are criticized by some university and industry researchers for their complicated application procedures, excessively rigorous reporting requirements, and lack of feedback or follow-through on conclusion. The involvement of the Department of Supply and Services as the contracting agent is the source of many of these difficulties. In general, the supervision and evaluation is felt to be of an administrative rather than a scientific or technical nature, and is often lacking in continuity, as scientific officers move to different responsibilities.

8c. Grants

As for granting bodies, the committee system for NSERC grants for university research is felt to be better for basic R&D than for applied funding. However, mining gets very short shrift from NSERC in both categories, and particularly in basic R&D, which should form the nucleus of university research programs. Concerns have been expressed concerning:

- the mixing of basic and applied R&D support programs;
- the rapidly expanding bureaucracy within NSERC;
- the criteria for selection of committee members;
- inadequate provision for equipment maintenance in operating grants;
- the concept and administration of strategic grants;
- lack of a committee of specific relevance to mining;
- the application of basic R&D criteria to applied proposals;
- the intention but not the practice of favouring interdisciplinary and joint-venture proposals.

NSERC, which does not have a mining committee, allocated only 3 percent of its operating grants, 2 percent of its strategic grants, and 1.3 percent percent of its equipment grants to mining and mineral processing in 1984/85. The grants to the mineral sector are approved by a variety of committees, as shown in table 7 for operating grants.

NSERC, NRC, and DRIE grants for industrial research and development have been useful sources of funding for some mineral firms. However, a major criticism of these programs heard from industry R&D administrators is that

Table 7

NSERC OPERATING GRANTS FOR MINING AND MINERAL PROCESSING, 1984/85

NSERC Committee	Mining	Mineral Processing
Civil	$522,900	-
Industrial	$83,500	-
Electrical and Mechanical	$53,700	-
Earth Sciences	$1,617,000	-
Chemical and Metallurgical	$20,000	381,200
Total	2,297,300	381,200
% of NSERC operating grants	1.8	0.2

Source: Marcel Vallée, "Mining and Mineral Processing Research and Teaching in Canadian Universities", CIM Bulletin, June 1986.

the application procedures, information, and progress reports required are out of proportion to the dollar value of grants, making some companies reluctant to use them. A notable exception is the IRAP grants, which are very simple in concept.

Basic R&D support programs should be seen as totally separate from applied, mineral-industry oriented, R&D. Basic research is outside the focus of this study, but it must be remembered that strength in basic sciences is essential if Canada wants to avoid relying on imported innovations and technology over the long term.

Recommendations

Here we propose a technology strategy for the mineral industry in Canada which has the objective of facilitating technological innovation, as a contribution toward maintaining Canada's position as a leading mineral producer beyond the end of the present century. Three distinct aspects are identified, which correspond to short, medium, and long-term time horizons in terms of expected results. All three aspects should be pursued immediately, if not sooner.

For the short-term objective, the strategy must provide the industry with the best available technology to ensure it remains viable and competitive. These recommenda-

tions are aimed essentially at catch-up activities. State-of-the-art technologies, in Canada or abroad, in mining or in other industries, should be acquired through such means as joint ventures, forward integration, purchase, or license, and should be implemented rapidly in areas of greatest need and opportunity. Promising new Canadian-developed technologies which are near to commercialization should receive special attention and funding to ensure rapid implementation.

The medium-term objective is to establish a solid base of technological capability and expertise in the Canadian private sector, still with a focus on technologies with quick returns in areas of greatest opportunity, but with increasing attention paid to developing domestic capability in methods and in equipment manufacturing, rather than relying on technology transfer from abroad.

In the long term, the objective is to establish Canada as a world leader in selected areas of mineral-related research and development, and in innovation in methods and equipment. Properly focused, this would ensure that Canada will remain a low-cost producer, as well as a supplier of new mineral products and materials with high value-added content. It would also have a viable mining equipment industry. Long-term viability in technological innovation must be built upon a foundation of strength in basic R&D.

However, the short-term concerns of the industry will not permit it to provide all the financial resources necessary to realize these objectives. Therefore, government should join industry in the necessary policy formulation and education activities, and offer financial support and encouragement for private sector implementation. It should at the same time continue to give strong financial support to basic R&D activities.

It should be noted that these recommendations were initially prepared in response to a request from the Ministry of State for Science and Technology, and therefore are disproportionately directed to government rather than industry initiatives.

Short-Term Recommendations

These are for immediate implementation, and aimed at economically sound short-term results in cost cutting and productivity improvement.

1. Private and public-sector efforts should focus on the acquisition and implementation of existing state-of-the-art technology.

The quickest and cheapest way to inject cost-effective new technologies into the mineral industry is to acquire them from available state-of-the-art sources wherever possible. Where such technology is not available, domestically or aborad, Canadian technical development should be encouraged in promising new technologies which have the potential for rapid commercialization.

2. Canadian industrial intelligence networks should be established and funded to ensure that the required information is obtained.

To implement this strategy effectively, Canadians have to examine what their colleagues and their competition are doing, and also understand the potential contribution of technical developments in adjacent industries for the mineral industry. In the present climate of economic constraint, many firms have slashed travel budgets and conference attendance. There are also very limited discretionary funds for monitoring developments in other industries. Governments could play a role in this respect by contributing to funding programs for these efforts. An on-line subject key-worded international patent information system would be a critical part of this activity.

3. Government support for demonstration and commercialization of promising Canadian-developed technologies should be increased.

A major barrier to innovation has been identified as the lack of funds available for the later stages of innovation, which are also the most costly. At present, EMR and NSERC offer support for the earlier stages of research and development, but the funding of subsequent steps is scanty. DRIE, which has the mandate to support the equipment manufacturing sector, specifically excludes mining per se. In addition, much of the required demonstration and piloting work does not take place inside research and development facilities in the mineral industry, but in the workplace instead, and is consequently ineligible for R&D support or tax treatment. A program to support demonstra-

tion and commercialization of technologies identified by industry as having high potential in identified areas of opportunity would almost certainly yield significant value.

4. The government should support the establishment of an industry-operated extension program designed to upgrade technologies in smaller mining enterprises that may have limited technical resources.

As noted in this study, most Canadian mineral enterprises do not possess any research and development capability, and their capability to change technology is limited, in most cases. Consequently, finding ways to facilitate effective technology transfer into these firms is of great consequence to their future survival. Using the Farm Extension Programs or the more recent program for coal mines implemented in the United States as models, a program of technology transfer should be aimed specifically at Canada's smaller mining enterprises, and could be a significant factor in their future viability. Existing agencies such as MAC, CIM, and particularly the provincial mining associations (which include the smaller firms among their members) could be used as a nucleus, and organizations such as CIM local branches could help with local presentations and contacts.

5. The industry, universities and governments should actively cooperate to promote understanding and better communication of technology-related issues, through:
   - stimulation of increased industry input to government decision-making processes related to mineral industry R&D and technology;
   - encouragement of increased cooperation between companies, in all industry sectors and within and beyond Canada, in technology development, commercialization and transfer;
   - establishment of university/industry/government sponsored management and technical courses.

There is clearly a need for improved understanding of the technical challenges facing the mineral industry. Senior corporate executives in Canada, unlike their counterparts in Australia, Europe and South Africa, have demonstrated

little willingness to develop significant levels of intra-industry cooperation in this area, through, for example, industry-wide R&D organizations. There is a need for increased understanding of the strategic and management issues related to managing technology. As noted earlier, industry has little control over government programs in support of their industry in this key area. There is a need for joint leadership from industry, university, and government in developing the necessary understanding and cooperation.

6. CANMET should assist the CIM and other mineral-related scientific and technical bodies in making their unpublished technical papers known to the industry, through MINPROC and MINTEC.

The MINTEC and MINPROC data bases are an existing vehicle that could be used for publication of titles and key words identifying CIM papers that are not published in the CIM Bulletin or Special Publications. The same could be done for the papers presented at all kinds of mineral-related technical meetings. Provision would have to be made for providing complete copies of the papers on request. This is a relatively small suggestion, but one that could be implemented quickly, at relatively little cost and with immediately useful effects, including both increased circulation of technical papers and increased industry use of the data bases.

Medium-Term Recommendations

These are intended for implementation over 1-5 years, starting immediately, and are aimed at medium-term results in increasing Canadian technological capability.

1. A target of 1.5 percent of revenues to be spent annually on technical development in the mineral industries should be attained by 1990.

Technical development in the mineral industries is presently under-funded both in an absolute sense, and compared to spending in other, similarly technically-intensive industries. A target of 1.5 percent of revenues, to be spent on all aspects of technical development (applied research, development, commercialization and transfer) would allow a substantial increase in Canadian capabilities.

The federal government should provide an incentive for the private sector by matching spending on, say, a dollar-for-dollar basis, although industry will have to be allowed a period of time to work up this level of support. This should be in addition to strong government support for basic R&D, which should have a totally different set of criteria for evaluation and justification.

2. Increased emphasis should be placed on the development of new and improved exploration and mining technologies, and on new product development, which are areas of both great need and great opportunity.

Exploration and mining technologies currently do not receive R&D funding corresponding to their importance to the mineral industry and to Canada. The federal government should direct a greater portion of its applied R&D funding towards these earlier stages in the mineral processing chain, and industry should increase its support of these areas as well. In metallurgy, the greatest R&D opportunities appear to lie in the development of new high-value-added products with good market potential.

3. Governments should provide funding and support for the development of increased mining equipment manufacturing capabilities in Canada. The mineral industry should also become actively involved in domestic equipment manufacturing.

A major barrier to innovation at present is the lack of Canadian suppliers with the size and scope of activities to work with the mining industry on major technical innovations which are embodied in new equipment and processing systems. This sector falls between two stools in terms of federal government support, being specifically excluded from EMR's mandate and effectively excluded from DRIE's support programs. Government grants and contracts for all stages of joint technical development projects between promising equipment firms and mining companies would provide strong support for an increased domestic capability in an area with export potential far beyond domestic demand. Industry support could take the form of joint ventures, forward integration, cooperation in provision of opportunities for piloting and demonstration, and other measures designed to share development risk and improve technology transfer.

4. Positive tax incentives should be offered by the federal government for all industry activities related to mineral technology development.

Traditional tax incentives have not been sufficient to stimulate the required levels of research and development in Canada's mineral industry. At present, in fact, many tax incentives are meaningless, since few companies are taxable; this situation is likely to prevail for some time. A number of novel approaches could be tried in this area. Flow through shares, similar to those for mineral exploration (but more tightly regulated than those recently offered for research and development), could be effective, since the industry is familiar with this vehicle. In addition, the federal government should recognize that much innovation in the mineral industries takes place in the workplace, and allow appropriate deductions for these similarly risky activities even when the development and demonstration phases are part of the production process.

5. Government grants for applied research and development and technological innovation made to private sector firms and universities should be matched by a significant industry contribution.

Much of the applied R&D work being carried out at present appears to have little commercial value to the industry, either because it is not relevant, or because it is not commercialized. To confirm industry's commitment to such activities, the federal government should require some corresponding contribution from individual firms or their technical cooperative associations, as soon as economic conditions, cash flows, and management attitudes permit.

6. Government research and development support programs for industry should favour joint ventures among companies, and include universities and end users whenever possible.

This will help to overcome the isolation and lack of "critical mass" that handicap some R&D efforts. HDRK and NiDI are positive industry steps in this direction of joint ventures, but both are experiencing difficulties in obtaining federal financial support.

7. Government support for applied research and development in universities should favour interdisciplinary studies and industry participation.

Interdisciplinary approaches will be required for major breakthroughs in fields such as biohydrometallurgy, process control, new approaches to rock fragmentation, robotics, etc. The NSERC evaluation criteria seem to discourage this approach at present; NRC's PILP program, by contrast, favours projects involving producers, users, and university and government researchers.

8. AN NSERC committee (or committees) should be established for funding of basic and applied university research in mining-related areas.

A clear distinction should be made between basic and applied studies. Especially for applied proposals, the committee should include some industry researchers, and cover fields including deposit delineation, mining, processing, and metallurgy. Proposals should be encouraged to be interdisciplinary, and to include industry participation in the research. Basic proposals should have a separate funding program, with predominantly academic criteria and evaluation.

Long-Term Recommendations

These are for implementation over 1-10 years, starting immediately, and aimed at long-term goals that will lead to Canadian strength in basic R&D in earth sciences and mineral-related fields, as well as Canadian leadership in mineral R&D and technology capability, and leadership in competitive position for production of a broad range of minerals and mineral products.

1. The basis for long-term science-based breakthrough technologies should be established by supporting existing and new bases of expertise in both basic research and mineral technology at Canadian universities, and in applied research in private sector facilities.

For the Canadian mineral industry to maintain a position of world leadership in selected areas of technology by the end of the century, the fundamental research programs

will have to be in place by the end of the current decade. In the Japanese fifth generation computer project, the government of that country played a leading role in creating a national industrial objective, and providing sustained support over the required time period. In Canada, industry and government should cooperate on a similar approach to focused objectives. In the initial years of this program, the required funding will be relatively modest, since basic and applied research are relatively low-cost activities, compared with demonstration and commercialization. There should be an emphasis on joint and cooperative ventures, and on cooperation between universities, few of which have the critical mass on an individual basis to support centres of excellence.

2. The Canadian mineral industry should establish a joint technical organization similar to AMIRA or the South African Chamber of Mines.

The scale and scope of the required technical developments require industry collaboration on a broad scale if success is to be attained. Such models of cooperation are becoming commonplace in the United States where mature industries are facing elimination by intense offshore competition. The pulp and paper industry in Canada provides a model, as well. There is an evident need for an organization which can coordinate research and development throughout the industry, focus R&D funding from all sources, establish cooperative programs, and ensure efficient diffusion and transfer of new technology throughout the sector. It would also insulate long-term development projects from the short-term economic vagaries of the industry.

3. Government should take immediate steps to increase the role of industry and universities in decision-making that affects government in-house activities and funding programs for applied R&D and technology.

The long-term goal should be the transfer of effective decision-making power in applied R&D and technology activities to the industry, as the potential end-users, and to universities as the principal source of expertise in basic research as well as participants in applied work. The transfer could take the form, for example, of establishing a governing council for agencies such as CANMET and NSERC

with majority representation from industry and universities. This would require a move away from departmental status.

An interim alternative for CANMET could be an increased emphasis on projects initiated by industry (or its joint research organizations) and funded jointly by government and industry. A "not fully funded" basis for government's contribution would be much simpler to initiate and operate than a "matching funds" basis. A distinction could be made between single-company confidential contracts and long-term higher-risk cooperative industry contracts in the public domain.

4. Government should take steps to minimize the problems of overlapping and sometimes conflicting departmental jurisdiction over mineral-related subjects.

While political pressures and overlapping interests of various economic sectors will prevent complete elimination of this problem, some consolidation and an improved focus on the technology needs of the mineral industry would be possible and constructive. Cooperation of the sort achieved by the Nonferrous Smelting Working Group provides one possible model.

5. Long-term R&D and innovations should focus on the development of methods and equipment based on currently emerging technologies.

Emerging technologies should not necessarily be R&D priorities for the mineral sector, but should be carefully watched for technology transfer opportunities. They include a wide range of disciplines and interdisciplinary studies not directly related to mining, such as biotechnology (for biohydrometallurgical methods), information technology (for data analysis, for process and operations design, and for automation and control of processes) robotics (for automation and remote-controlled equipment), nuclear physics (for sensing and measuring devices), etc.

6. Industry, academic, and government decision-makers should stay informed on long-term trends in the mineral industry, and work together to

adjust the focus of R&D and technology efforts as required.

Structural changes in mineral supply and demand over the years will affect Canada's long-term comparative advantage, and dictate shifts in emphasis in terms of minerals sought, stage of processing appropriate in Canada, product quality and diversity, etc. Government sources of information such the Mineral Policy Sector of EMR should maintain close contacts with academics, and place emphasis on anticipation of trends. They should also continue to keep close contacts with industry, in Canada, in competing countries, and in existing and potential mineral markets. It must be remembered, however, that R&D is a long-term process and cannot be turned on and off capriciously, or within arbitrary time limits.

THE CHANGING ROLE OF RESEARCH AND DEVELOPMENT IN THE CANADIAN MINING INDUSTRY

Frank Pickard

Introduction

The role of research and development in the Canadian mining industry is undergoing significant change, for a number of reasons. Research and development activities have been increased in the following areas:

- improving of working conditions and work methods, with the objectives of improving employee safety and productivity;

- decreasing the emissions of a variety of substances, to improve both the external and internal environments associated with mining activities;

- increasing metal recoveries and enhancing the value of the final products;

- protecting existing markets and developing new applications for products.

The increase in some of these R&D areas has been brought about by the necessity to meet revised legislation, particularly with respect to working conditions, safety and environment. The increase in others has been the result of changing world economic conditions, particularly with respect to metals production and marketing. Survival, in competition with developing nations that neither pay the high wages nor have the costs associated with improvements in working conditions and the environment which we have in Canada, has meant becoming even more innovative, and placing more emphasis on selective areas of R&D, than was generally the case ten years ago.

Mining Research and Development

Mining R&D groups have existed within the Canadian mining industry for many years. They have tended to be small groups, with one or two engineers, a few technicians, and very low budgets. Often their R&D activities were part of

the departments which had responsibility for paying the mine bonuses, and their activities were devoted more to time and motion studies than they were to developing new methods of doing things. In spite of the general lack of formal recognition which they received, they still succeeded in implementing significant changes. My first experience with mining R&D groups was in 1951, when Falconbridge was experimenting with the use of deslimed mill tailing as backfill. This experiment was a success; however, I can still recall the many discussions we had with the single mine research engineer over the fact that we had a number of metallurgists involved full time in R&D while it was essentially a part-time job for him.

Times have changed. While changes in mining methods used to be slow and almost ultra-conservative in nature, we now see much more significant change being made, at much faster rates. Mining R&D groups have grown in size and people are now employed full time at R&D. It is no longer unusual to find mining engineers in graduate schools studying for their masters or doctors degrees with the final objective of continuing their research activities after obtaining employment in the mining industry. There is a commitment on the part of mining companies to increased levels of expenditures on mining related R&D. No longer do the metallurgical plants receive all of the research and development dollars.

The list of changes in mining methods and mining equipment in the past twenty, ten, or even five years is lengthy. The movement has been to less labour-intensive mining methods which result in less exposure of the miner to hazardous conditions. This has been accomplished by use of increased mechanization and by revising mining methods to minimize the risk of injury and to increase productivity in the mines.

These changes in the role of technology resulted from two major sources of pressure:

- the need to make mining operations safer and improve general working conditions;
- the need to improve productivity to be able to compete on world markets.

The changes have been accomplished by increasing the role of R&D so that it is an integral part of mining operations, with full-time staff, adequate budgets, and commitment from management to develop or acquire technology for use in the mines. The movement is perhaps best illustrated

by Inco's Copperclff North mine, which is dedicated to acquiring or developing and implementing new mining methods and equipment. As a result of these successful efforts to improve technology it has the highest productivity of any of the mines in the Sudbury area.

To better evaluate the changing technology, four mining companies have formed a group with the objective of cooperative ventures in the field of developing and testing new mining methods and equipment. This is a radical departure from the days when each company did its own mining R&D with little or no sharing of information, an approach which often resulted in duplication of efforts and expenses.

What is needed now is expansion of this joint effort concept into other areas, such as metallurgical R&D.

Environmental Research and Development

There has been, still is, and will continue to be pressure from environmental groups on industry to reduce and eventually eliminate emissions of a variety of products from industrial activities. These pressures, combined with acceptance by industry of the social responsibilities related to environmental issues and with greater knowledge of the potential detrimental effects of certain emissions, have resulted in increased legislation by various levels of governments to control emissions. The outcome has been an increase in R&D activities related to environmental problems in the Canadian mining industry.

It is no longer sufficient to develop a new mine or metallurgical process simply to recover more metal or to recover it more efficiently. One must also design the process to be environmentally acceptable, both for present regulations and for regulations which are anticipated in the future. Existing processes have to be modified to meet reduced limits of allowable emissions, whether they be solid, liquid or gas. This has changed the role of R&D in the Canadian mining industry. The research dollars spent on environment-related projects are increasing at a rapid rate.

Falconbridge Limited spent 44 percent of its metallurgical R&D budget on environmental programs in 1985, up from 25 percent in 1984. At Falconbridge we have recognized that we are going to be required to continue to make modifications to our processes in order to reduce emissions of undesirable substances. We have redirected our R&D activities to accomplish this, but we also recognize that conventional ways of reducing emissions are usually not

very cost effective. We have thus not only redirected our efforts to reducing emissions, but also to new approaches to emission controls, to make sure reductions will be cost effective in the overall scope of our operations. We are probably not alone in this approach.

Metallurgical Research and Development

The field of R&D in the mining industry with which I am most familiar is that of metallurgical research and development, and most of what I have to say is related to recent experiences at Falconbridge Limited. Falconbridge has conducted metallurgical research and development activities since its inception over 50 years ago. Its R&D facilities were originally located at the minesite in Sudbury and at the Norwegian refinery. In 1953 a central research laboratory was established in Richmond Hill, just north of Toronto. Pyrometallurgical and mineral dressing R&D continued to be carried out at the minesite, but the bulk of hydrometallurgical and product development R&D was assigned to the central research laboratory, which was appropriately called Falconbridge Metallurgical Laboratories or FML. This facility was expanded several times and at its peak employed slightly more than 100 people. In 1977 the pyrometallurgical R&D function was also transferred from the minesite to FML. The R&D budget peaked at a little more than $11 million in 1981.

In 1982 the bottom fell out of the nickel market. The producer price of U.S. $3.20 per pound became meaningless and the price of nickel on the London Metal Exchange fell to U.S. $1.42 per pound. We reacted by slashing costs wherever we could so that we could survive. One of the areas where we cut deeply was in R&D. The size of the group at FML was cut to 60, then to 37.

We looked at what we were doing in the R&D programs and at what we were planning to do in the future. R&D had paid off for us in the past. The process for treating the nickel-bearing laterites in the Dominican Republic had been invented and successfully developed through pilot plant stage to a commercial plant. A new refining process had been invented and the technology successfully transferred to the Norwegian refinery. A new smelting process had been developed and implemented. Numerous refinements to process and to products had been pioneered by the R&D group. Now we were faced with what to do with the group when we could no longer afford to support it in the manner in which we had in the past.

Falconbridge had adopted a "no frills" approach to its operations. FML with its nice but not luxurious building and grounds did not fit this concept. It cost too much money just to open the doors of the establishment, and in January 1984 it was decided to close FML and transfer the bulk of its staff to the minesite. We were going back to where we had been in 1952 prior to opening FML. Some of the staff for personal reasons elected not to accept the transfer to Sudbury. Some elected early retirement and others accepted termination of their employment. Included in the former group was our very capable general manager. In making the transfer it was decided that metallurgical R&D would continue to be a corporate function and that the facility at the minesite would receive its "rum and rations" from the Sudbury operations but continue to report to the corporate vice president.

The move provided us with the opportunity to review what was good and what was bad about our R&D programs and about how we implemented the results of successful programs. It also resulted in severe depletions in staff, and presented us with the opportunity to restaff, with changes in emphasis on R&D programs, if that was what was required. Our new manager had spent part of his career in R&D and had also worked as an operating plant superintendent. He had the task of restructuring the R&D organization.

We found that under the old system there were four hurdles to cross between conception and commercialization of new technology:

- first, the research group developed the concept and tested it on a lab scale;
- then the process technology group at the minesite had to be sold on its merits;
- if this was accomplished, the third step was selling the operators on the usefulness of the technology;
- the fourth step involved having the design engineering group draw up the plans for its implementation and look after construction of the test and commercial units.

In each step there was a certain amount of "not invented here" (NIH) syndrome involved in getting anything accomplished.

It was decided to combine a number of these functions and change the title and concept of the research group. The new organization was called the Metallurgical Technology Centre (MTC) and included the former minesite pro-

cess technology, design engineering, and construction groups. These latter three groups were amalgamated to form the Metallurgical Systems Group and, in combination with the research group, they were given the responsibility to invent, develop and implement new technology. The operators, of course, had to be in agreement with any technology proposed for implementation in their plants. Since the operators were under continuous pressure to improve operations, they were quite agreeable to anything which could be demonstrated to improve their operations.

At the same time, it was realized that we could not afford to employ permanently the staff specialists which we had previously had on our payroll. We decided that we would use the expertise of consultants more frequently. We had used consultants in the past, but the tendency was to not to take full advantage of their technical expertise. Consulting firms were a source of engineers and draftspeople for specific projects, and were expected to do what they were told and not to try to muddy the waters by coming up with new ideas. Now we were going to hire engineers and use their expertise more fully. The first project on which we used this approach was the Kiena Mill; the consultants were amazed at how we had changed in our approach, and we were somewhat surprised by just how much more the consultants had to offer than we had utilized in the past. We have repeated this exercise on several occassions since and find it is quite satisfactory. We do not know everything and we are now more ready to admit it. The NIH factor is disappearing and the projects are flourishing.

There is one prime example of the success which the MTC has had with the new approach. One of the problems in smelting of nickel-copper concentrate is achieving reasonable recoveries of cobalt. For many years our various R&D groups have worked on schemes to increase cobalt recovery. Another concept was being developed about the time that FML was closed down which would not only result in improved metal recoveries but would also assist us in our quest to reduce sulphur dioxide emissions. Operator interest in the concept was minimal. After setting up the MTC group, work on the concept continued. The MTC personnel sold the operators on the idea and a joint team was set up to develop and implement this technology further. In about a year they had not only tested the process in the smelter but redesigned a converting vessel and implemented the new technology as part of the regular smelting operations. Some R&D remains to be carried out before the project can be considered to be commercialized but we are confident

this will be accomplished. This project offers benefits both from increased recovery and from the potential to reduce sulphur dioxide emissions. Over 250 people were involved before the project was successfully completed.

Summary

The Canadian mining industry is an important component of the Canadian economy. In 1984 the value of minerals and metals production was about $20 billion, of which about $16 billion was exported. Direct employment is about 145,000 people in about 175 different communities. The multiplier for the mining industry has been estimated to be about 3.5, which means that about 500,000 jobs are dependent upon the minerals and metals industry.

Canadian products must compete with metals produced by developing nations which have lower wage rates and fewer costs associated with environmental and occupational health aspects of mining and processing ores. In order to compete on the world markets, where we are price takers and not price setters, we must have better productivity and more sophisticated technology so that we have lower costs than our competition.

To accomplish this we must change the role of research and development in our industry. We must get rid of the NIH factor and implement technology which has been invented by others. We must learn to share our R&D costs and the results of the shared developments. We have a start on cooperation in R&D with HDRK, but it needs to be expanded beyond what is now only three companies, to include the smaller producers and to encompass more than just mining research.

We must also drop the conventional approach to R&D which involves too many hurdles from the conception of a possible new technology to its actual implementation. What we have done at Falconbridge in this respect is a giant step in the right direction. We have combined the research and development functions with the design and construction functions so that there is smooth flow and control over research projects from conception to commercialization. It may not be perfect yet but we are working towards that goal.

Before concluding my remarks I must add that the Canadian mining industry in most cases has made substantial cost reductions to meet depressed metal prices. These have been accomplished by a variety of mechanisms including the closing of marginal or unprofitable mines, layoffs of non-

essential employees, improving management, and reducing spending in all areas including research and development. The challenge now is to obtain the necessary funds to conduct meaningful R&D programs. In the past, R&D was frequently viewed as being something nice which only the larger companies could afford. Today it must be viewed as a necessity which all companies both large and small must support. It is only through development and implementation of improved technology that the industry will survive against the competition.

BARRIERS TO INNOVATION IN THE MINING INDUSTRY

Donna M. Bevelander

Industry's Attitude Towards Innovation: A Survey

For many years, achieving and maintaining a competitive position in mineral production depended primarily on access to export markets, the orebody itself, of course, and some reasonable financial support. But intensified pressure from many developing, as well as long-established, foreign competitors has forced the Canadian mining industry to examine ways and means of improving its productivity in order to maintain competitive status. The key role that new technology plays in productivity improvements is well documented and increasingly recognized. Obviously, the development and application of new technologies can provide the desparately needed productivity boosts. But is it obvious?

If it is obvious, why does the mining industry, one of the most capital intensive of industries, devote less than one percent of gross revenue to research and development and market research combined? What factors deter the development and application of new technologies in the mining sector?

CANMET is intensely concerned with technology transfer and therefore concerned with the answers to these questions. They retained our firm to conduct a survey of the industry in order to provide them with the industry's perspective of the barriers and constraints to the application and development of technology. The results of the survey are interesting, enlightening, surprising and, at the same time, both disheartening and encouraging.

The questionnaire itself was designed with the close cooperation of The Mining Association of Canada and with significant input from industry representatives involved in MAC's research and technology committee. The questions cover the current level of utilization of state-of-the-art equipment or processes; recent innovations; planned investments; information sources; government programs; barriers and constraints; cooperative R&D partners; and opinions and suggestions on technology diffusion.

Given the amount of information and the time constraints, not to mention the thought-provoking information already presented here by previous speakers, I will only outline a few of the findings. First, let's look at the sample. We sent out 448 questionnaires and received a

response rate of 29 percent overall. The questionnaires were directed at individuals within three levels of the corporate structure: executive, research, and operating management. The responses cover each of the three levels, with a 40-percent response rate from executives, 25 percent from research and 35 percent from operating management. The majority came from organizations with three or fewer mines in Canada. The three groups are well distributed across type of operation. In other words, there is representation from executive, research and operational groups from organizations that operate underground only, open-pit only, mixed, and those that have smelters. We are satisfied that the sample is representative of the industry and is not slanted by type or size of operation.

Recent Innovations Reported

Respondents were asked to identify what and when was the most recent installation or application of a new process or piece of equipment in their operations. Seventy-two percent indicated that the most recent was in 1985-86. Another 23 percent indicated the period between 1980-84. This is important because it demonstrates not only that the industry is currently active in innovating or upgrading, but also that the subsequent specific questions regarding this installation reflect, not a historical or traditional perspective, but the way things are being done now. Table 1 shows that, of these recent installations, 50 percent were pure purchases while another 21 percent include value-added work on purchased goods. Only 16 percent were developed solely in-house.

Table 1

SOURCES OF RECENT INSTALLATIONS

Source	Percent
Purchased	33
Purchased & customized by vendor	17
Purchased & adapted in-house	21
Combination purchased & developed in-house	8
Developed in-house	16
Combination of all	5

This does not necessarily mean that only 16 percent of the firms have in-house development capability, because 55 percent of the sample indicated the presence of a formal R&D or technology development group within the firm. Why then only 16 percent? I believe this is because the research and development personnel are not often charged with the responsibility to invent; rather, they are charged with adapting existing technology and implement in-house scientific and technical knowledge in support of the operation. They are the collectors of technology-related information and key players in the technology transfer process.

The findings also indicate that the research group obtains more value, in the form of technology-related information, from conferences, colleges and universities and government laboratories than the other two groups. I believe they form the linkages to the scientific community and that they are the loci for information exchange. Do they also drive the innovation process? Yes and no.

In 46 percent of the recent applications of new technology reported, the need for innovation had been identified by the operating management and staff, as shown in table 2. The research group was responsible for identifying the need for 31 percent of the innovations. Six percent came from some combination of the three groups. This means almost half of the recent installations were driven by the operations people; they truly "drive" the innovations being implemented. It is common practice, according to the respondents (72 percent), that those who identify the need are also charged with finding the technological solution; in 48 percent of the cases, that same person or group then presents the project to the executive level for approval.

Table 2

IDENTIFICATION OF THE NEED FOR MOST RECENT APPLICATION

Identified by:	Percent
Executive	14
Research/engineering/technical	31
Operating management & staff	46
Combination	6
External (gov't & consultants)	3

Although this "up-from-the-bottom" approach affords many advantages and allows room for important incremental improvements in many phases of the mining process, it also imposes severe limitations. Such a heavy emphasis on "up-from-the-bottom" proposals may well tend to minimize pressures for far-reaching new kinds of technology. Clearly, it does not suggest the existence of an overall corporate technology strategy. Some of the reasons can be deduced from the attitudes reported below.

Attitudes to Innovation: Its Contribution to Profitability

It must be recognized that major technological improvements usually involve substantial investments and risks, in addition to taking extending periods before their full potential is likely to be realized. Therefore, major technological advances are not likely to be pursued unless top management identifies them as priorities. Only when the CEO makes the commitment will the climate for change be established, and only then are the conditions right for the company to develop and apply advanced technologies.

But private firms are not in business to advance technology or even to maximize productivity. They are in business to achieve and maintain attractive rates of profitability. Does the industry recognize the link? Is technology perceived to provide a significant contribution to the profitability of the organizations?

Respondents were asked to rate and rank nine factors[1] in terms of their potential contribution to profitability. In the overall rating, technology is in fourth place with 62 percent, indicating it provides a significant contribution.

However, in the ranking of the top five factors, there is a marked deviation in the evaluation of technology within the three groups. As you can see from table 3, technology does not even appear on the executives' list. It holds third place for the research group and fifth for operations.

What, then, motivates the industry to innovate? The three most frequently cited factors influencing the decision to implement the recent applications were cost savings and profitability (64 percent), productivity and efficiency improvements (43 percent), and health and safety (15 percent).

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1. The nine factors in order of aggregate ranking were: management, labour force, cost control, technology, equipment maintenance, marketing, exploration, end product, diversification.

Table 3

RANKING OF THE TOP FIVE FACTORS, BY TYPE OF RESPONDENT

Respondent	Rank	Factor	Mean
Executive	1	Management	3.9
	2	Labour force	2.7
	3	Cost control	2.3
	4	Marketing	1.2
	5	Equip. mtce.	1.1
Research	1	Management	3.2
	2	Labour force	2.3
	3	Technology	1.8
	4	Cost control	1.7
	5	Equipment mtce.	.9
Operations	1	Management	2.5
	2	Labour force	2.4
	3	Cost control	1.7
	4	Equip. mtce.	1.3
	5	Technology	.9
Total Sample	1	Management	3.2
	2	Labour force	2.5
	3	Cost control	1.9
	4	Technology	1.2
	5	Equipment mtce.	1.1

Let's go back for a minute. I said that 46 percent and 31 percent of the need are identified by operations and research respectively. I also mentioned that in almost half the cases the same entrepreneurial person or group pushes the change internally through the organizational system and finally makes the presentation to the executives for project approval. We know that profitability and cost savings are the primary motivators to innovate.

How well equipped are the research and operations group to present management with an analytical framework which facilitates tracing the probable effects of technological innovations beyond productivity to the resulting impacts on costs and profits? Are they sufficiently well-versed in corporate financing and long-term goals to explain the significance of major technical projects to the current and

future business of the corporation? I don't know the answer and our survey did not address this, but I suspect that the geographic remoteness of research and operations from the head office where corporate priorities are set, combined with the pressures of day-to-day operations, does not allow for the development of such a comprehensive analytical framework. As one respondent eloquently commented: "industry is often too busy fighting fires to design a better fire retardant" - let alone develop a justifiable financial case for the fire retardant!

But let us assume for the moment that this entrepreneurial group or person pushing for the incremental improvement does have the time and the information to put together a justifiable financial case. There is yet another barrier, for even these incremental improvements are usually evaluated against profits anticipated from the innovation during its years of use, discounted back to the present at say 20 percent annually, for comparison with the required investment. This means that virtually every innovation which cannot be purchased or developed, installed, debugged and brought to full utilization within two or three years is likely to be rejected.

However, management should consider not only the incremental profitability of an innovation but also the decline in profitability which may result from rejecting the innovation. Maintaining technological competitiveness requires a continuing program of upgrading rather than occasional surge efforts. If the major advances needed to ensure continuing competitiveness require more than 2 or 3 years to come to fruition, then a longer-term perspective is essential.

However, these are my speculations. Now let us examine what the respondents defined as the constraints and barriers to technology development and diffusion.

Attitudes to Innovation: Constraints and Barriers

The survey questions on contraints and barriers centred around human resource, technical and economic factors which may represent barriers to the introduction of new technologies. The respondents were also given ample opportunity to suggest other constraints which we may not have included. Of the 21 barriers they were asked to both rate and rank, the two foremost are:

- risk involved in unproven technology;
- cash availability.

Taking the human resources set of barriers first, we see from table 4 that management attitude is identified as a barrier by 28 percent of the respondents. Notice that the research group in particular, considers management to be a constraint, with 42 percent identifying it versus only 11 percent of the operations people. Also note that 24 percent of the research group identify corporate structure as a significant barrier.

In terms of technical barriers, table 5 indicates that risk involved in applying unproven technology is head and shoulders above the rest, with 65 percent. The executive group is more risk averse than the other two, but they too nonetheless most frequently identify risk as a significant factor. The key word is "unproven". In the open-ended questions, several respondents identified the need for an experimental mine where new technologies can be piloted and proven. Countries like Sweden and Finland have used experimental and demonstration mines for years; why not Canada?

Under economic constraints, cash availability scores very high across all groups, as shown in table 6. The challenge as identified by the respondents is quite simply that the need to innovate in order to increase productivity and remain competitive comes at a time when industry is cash poor and operating in uncertain markets.

The responses to the open-ended questions indicate that their solution, equally simply, is to increase the liaison between all the players in the innovation process and to encourage more cooperation between members of the industry itself. Also, the respondents felt that the dissemination of information could be greatly improved. Several mentioned more frequent regional forums and on-site seminars, newsletters from unbiased sources, and a central clearing-house for technology-related information.

Where are they currently obtaining their technology-related information? How do they feel about its usefulness? Let us look at the survey results again.

Enhancing Technology Transfer

The majority of respondents indicated that they obtain the most value from in-house expertise, personal contacts in industry, trade journals and publications, and visits to other Canadian firms and suppliers.[2] The sources felt to

2. The 16 sources, listed in order of ranking, were: in-house expertise, personal contacts in industry, trade journals and publications, visits to other

Table 4

RATING OF HUMAN RESOURCE BARRIERS TO TECHNOLOGY

Human Resource Factors	Percent of Respondents Who Identified This Factor as a Barrier			
	Total	Executive	Research	Operations
Management attitudes	28	32	42	11
Lack of in-house expertise	26	29	18	28
Identifying appropriate outside expertise	25	28	23	23
Availability of required skills	25	23	32	20
Employee attitude	19	20	16	21
Union issues	15	12	20	13
Retraining	12	9	10	15
Corporate structure	11	7	24	6

Table 5

RATING OF TECHNICAL BARRIERS TO TECHNOLOGY

Technical Factors	Percent of Respondents Who Identified This Factor as a Barrier			
	Total	Executive	Research	Operations
Risk involved in applying unproven technology	65	71	66	61
Retrofit Problems	41	49	42	30
Difficulty in modifying available technology	33	42	30	24
Difficulty in optimizing future flexibility at design stage	24	13	31	31
Inadequate information about available technology	24	24	25	20

Table 6

RATING OF ECONOMIC BARRIERS TO TECHNOLOGY

Economic Factors	Percent of Respondents Who Identified This Factor as a Barrier			
	Total	Executive	Research	Operations
Cash Availability	71	69	70	74
Financing Support	52	46	65	53
International Economics	50	50	42	57
Hidden Costs	45	52	47	36
Benefits	44	47	49	37
Rising Fixed Costs	38	33	46	37
Detailed Existing Costs	29	31	21	33
Duties and Tariffs	7	8	7	2

be of least value include government laboratories, colleges and universities, government departments, and provincial technology centres. Clearly, there exists an opportunity to strengthen the linkages with the latter group of sources, particularly with the operations groups, which placed the most negative value on that set of sources.

But is the industry willing to build these linkages, considering the current perception of value. The answer is resoundingly yes. The need for closer linkages and co-operation between the industry, its suppliers, the government and the universities is reiterated again and again in the opinion section of the survey. Here are a few quotes in answer to the question of what could be done to further the development and diffusion of appropriate technology.

From the executive group:

- Foster two-way communication between industry and research agency personnel on a continuing basis.

- For development of technology - closer liaison between universities, government, and industry regarding the needs of industry and emerging technology.

From the research group:

- Continued development of government, academia, and industry linkages, but this will require more selling from government labs and technology centres and universities.

From the operators:

- Adequate meetings are held but sometimes small companies just can't afford to send young engineers to meetings. Government aid might help. Possibly tours of mines by technical people from universities and government could help diffuse technology.

Canadian firms, suppliers, consultants, visits to foreign firms, seminars conferences and courses, newsletters and bulletins, industry and professional associations, exhibits and shows, business and technical data bases, government laboratories, colleges and universities, government departments, provincial technical centres.

- Greater cooperation between industry, government and suppliers.

Concluding Comments

Obviously there are many opportunities for improvement. The survey gives us some answers regarding the issues involved in technology diffusion. It provides a clear and concise statement of industry's perception of the problem and it gives their solution.

It also raises a host of questions that must be answered if their solution is to become a reality. How is technology-related cooperation encouraged? How can the junior mining companies become involved in research? What deters the liaisons between key players, i.e. government, universities, suppliers and the industry? How can these linkages be strengthened? What role should each player have in efforts to coordinate cooperative research? How can information exchange be maximized?

Whatever the answers, ultimately the onus remains on senior management, because what is required is a far-reaching reorientation of management perspectives. This is not likely to be effected rapidly, but even the inertia of long-established attitudes and risk aversion may diminish under the pressure of intensified competition. Only a fuller appreciation by senior officials of the critical bearing of technology on their competitiveness within the next 5 to 10 years is likely to generate the top-level commitment necessary to motivate and support effective development and implementation efforts and also to generate the "top-down" pressure for overall planning and application.

As for universities, technology centres and government laboratories - they have a selling job to do. The current links with industry research groups is a start, but they need strengthening. Furthermore, direct linkages must be established with the operations people. In the absence of an overall corporate technology strategy, the operators are the in-house champions; and busy ones, at that. These outside organizations must be the aggressive initiators of the linkages, promoting innovation within the industry.

FUTURE DIRECTIONS FOR CANMET: A VIEW FROM THE STEEL INDUSTRY

John E. Hood

Introduction

The steel industry in Canada is of vital importance because of its size as an employer, the volume of its exports, and its significance as a supplier of materials to the secondary manufacturing industry. The continuous development and implementation of new technology by the steel industry will be a key factor in maintaining its health in the face of offshore steel competition and competing materials.

CANMET plays an important role in maintaining this health through the direct and indirect development of steel-related technology. My purpose in talking to you is to review the present status of the steel industry, its technological needs and how it has tried to satisfy them, and to suggest how CANMET can increase the effectiveness of its support.

My views will be representative of a particular large, integrated steelmaker and so may be different from those of other steel companies. However, I have been exposed to a range of perspectives through my involvement with the National Advisory Committee on Mining and Metallurgical Research and so I hope to present a reasonably balanced viewpoint.

Steel Industry Profile

The Canadian steel industry has an annual capacity of 18 million tons of raw steel, and directly employs about 50,000 people. About 250,000 people are employed in secondary manufacturing industries that are heavily dependent on Canadian steel.

There is a large steelmaking overcapacity in the world which has arisen because of the priority that domestic steel production has received in some developing countries, such as Brazil and South Korea, and the declining growth rate for steel demand. The new offshore steel producers have low construction costs, modern facilities, and low labour rates and so can produce some of the lowest-cost steel in the world today. An important factor affecting steel demand is the rapidly increasing challenge from competitive

materials, such as engineering plastics. In the face of these pressures the Canadian steel industry is looking, more than ever before, to new technology to improve its competitive position.

Technological Needs of the Steel Industry

It is not my intention to list all of the technological needs or barriers perceived by the steel industry, but rather to present to you some of the major factors that are creating these needs and to discuss the mechanism that has been used by the steelmakers, as an industry approach, to address them.

There has been a revolution in the North American steel industry during the last five years as steel demand dropped, prices fell and "quality" become the watchword. The emphasis on improved quality led to the widespread use of statistical process control (SPC), which is the ongoing application of statistical analysis to product and process variability as a means of assessing process capability and ensuring that the product meets the specified requirements. SPC is seen as a major tool for reducing product variability, which is an important requirement of steel users. The application of SPC is also leading to insight into process limitations, and to an increasing need for improved process sensors so that the process performance can be monitored more accurately.

In today's sluggish market, where growth is mainly at the expense of another producer, there are increasing incentives for product development. These incentives have led to the widespread use of secondary steelmaking for enhancing the purity and precise chemical control of steel. Also, there are steadily increasing opportunities for higher strength steels, primarily in the automotive and pipeline industries, and for improved corrosion-resistant steels for both automotive and construction applications.

Canadian steel companies are trying to satisfy their need for improved technology through a variety of routes: in-house research; contract research; cooperative research with universities, government and customers; purchased technology; and the Canadian Steel Industry Research Association (CSIRA). CSIRA was formed in 1978 to develop industrial relationships with universities and government laboratories, in order to try to channel a greater proportion of their research efforts in directions which would benefit the steel industry as a whole.

CSIRA began by organizing many steel-industry/university meetings with the objectives of both acquainting universities with steel industry technological needs and acquainting the steel industry with the universities' research capabilities. After this phase, many "orientation" activities were arranged, to further raise the academics awareness of steel industry needs and to explore means of communication and cooperation. These activities included:

- CSIRA-organized technical sessions at the CIM Annual Conference of Metallurgists in which joint papers were presented in part by the industrial coauthor and in part by the academic coauthor;

- a DRIE-initiated and CSIRA-organized visit to West Germany steel research establishments by five Canadian professors working in steelmaking process modeling;

- a two-day workshop on the sensor needs of the steel industry, in which industrial representatives presented the needs, current approaches and operating environments of the various sensors, and university and government researchers presented their relevant ongoing work and suggested future action;

- a Japan-Canada seminar in Tokyo on secondary steelmaking in which academics, federal government and industrial representatives participated;

- an international conference organized by CANMET and CSIRA entitled "Inclusions and Residuals in Steels: Effects on Fabrication and Service Behaviour";

- the endowing of a CSIRA-NSERC chair in steel processing at McGill University, which has been accepted by Professor John Jonas.

These activities, over the last seven years, have led to the following observations:

- industry must take the initiative in encouraging cooperation, must open its doors to academic and government scientists, and must be prepared to shoulder a reasonable share of the research costs;

- university researchers should concern themselves with industrial problems and learn to work across institutions to gain the benefits of synergism;

- government researchers should conduct generic applied research and facilitate university-industry teamwork;

- all three - universities, government and industry must share the common purpose of transferring technology from the technical community to the market place.

The Role of CANMET

I reviewed the document "Mining, Mineral and Metals Technology and the Role of CANMET", issued by CANMET in 1983 in preparation for this presentation. CANMET stated that its mission is to provide policy-related information to the Minister, to support government social objectives for health, safety and the environment, and to support industrial R&D aimed at improving economic performance and productivity. As CANMET considers the first two of these mission goals to be "inelastic", I will confine my comments to the goal concerned with supporting industrial R&D, which represents about 55 percent of CANMET's resources. I found myself in broad agreement with the objectives and strategy described in this document and so I will focus on those aspects which I believe should be given a high priority.

Clearly, CANMET has many constraints on the type of R&D it can support; it should neither compete with private research institutes or universities nor perform R&D that is best performed by industry. Rather, CANMET's role is to encourage and support R&D in industry and universities and to perform the more generic applied R&D that bridges the gap between university fundamental research and industrial developmental research.

Research Program Selection

Being relatively small, CANMET must take great care in the selection of the R&D it undertakes to promote. Communication with industry to determine its needs, its longer-term strategy and, as far possible, to obtain industry's commitment to the implementation of new technology, once developed, is a key aspect.

Industry organizations such as CSIRA can provide a convenient communication channel to help identify technological needs and certainly CSIRA is eager to undertake that role. Also, other means of communication such as seminars, workshops, industry-government task groups, and

direct meetings between CANMET researchers and their counterparts in industry have all been used in the past and found to be helpful.

Establishing priorities for industry's needs that have been identified through the sort of communication discussed above is a most difficult problem. It requires clearly defined criteria that are weighted in importance if objective ranking is to be achieved. CANMET has defined its criteria[1] in general terms as government policy, the economic situation, potential public and industrial benefits, probability of success, the magnitude and time-scale for benefits of successful R&D, and the human and financial resources available. However, the articulation of more quantitative or specific criteria would help industry to find a fit with CANMET's objectives, or at least to argue the validity of CANMET's criteria where there is disagreement.

Another important factor in selecting the best research programs is the commitment of industry to adopt the technology, once developed. It seems unlikely that industry will feel committed unless it is deeply involved in the development of the technology in the first place! Such involvement may be financial, through at least the partial co-funding of the research performed by CANMET or financed by it at universities; or technical, through the establishment of joint industry-CANMET research programs. In these cases, front-end commitment is assured and, as important, close involvement by industry during the research program is encouraged. Financial or technical participation in the research performed or funded by CANMET, by the industry for which the technology is being developed, should be a prerequisite.

Technology Implementation

CANMET's success in applied research can only be measured in terms of the extent to which the technology developed or fostered by CANMET has been implemented by industry, and the value of that implementation. Applied researchers often mistakenly believe that their task is completed once the technology has been developed and "transferred" - usually interpreted as "communicated" - and yet implementa-

1. Mining, Mineral and Metals Technology and the Role of CANMET, 1983, Canada Centre for Mineral and Energy Technology.

tion is frequently an equally difficult task and is essential to give value to the research. In many companies, the researcher is charged with implementing the technology; this has the advantage of focusing researchers on the practical constraints for implementation at the beginning of the research program.

Because CANMET is one step away from the end user, implementation must be of special concern and may be particularly difficult. In reviewing the functions of CANMET's Office of Technology Transfer in the 1983-84 CANMET Review,[2] it appeared that a primary focus was information transfer rather than technology implementation. It is not clear who has the main responsibility for implementing technology developed by CANMET.

Making the CANMET scientist who was responsible for developing the technology also responsible for its implementation or monitoring the implementation and cost/benefit analysis is one possible approach to this problem. Obviously, it would be impossible for the CANMET researcher to do this without the full cooperation of industry but, as discussed previously, that sort of commitment should be obtained before the research is begun.

As the public purse strings are pulled tigher, the need for a clear demonstration of return on technological investment increases. While assessment of the value of R&D is extremely difficult, it must be done, in order to support future efforts. The support of those companies employing the new technology is essential to determine the rewards arising from its use but, again, can it not be made a precondition for CANMET's support at the outset?

National Facilities

CANMET operates a number of "national facilities" which, because of cost or specialized application, could not be justified by individual companies. These facilities are generally accessible to industry on a cost-recovery basis.

Many of CANMET's national facilities are of importance to the steel industry and advantage is taken of them to an increasing degree. They provide a unique capability in Canada and must be maintained. In many cases, the application of these facilities on a cost-recovery basis could lead to more closely-coupled cooperative research programs, which I believe will provide the greatest return on CANMET's effort.

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2. CANMET Review 1983-1984, CANMET Report 84-8E, Canada Centre for Mineral and Energy Technology.

Conclusion

The Canadian steel industry will be heavily dependent on new technology to help it combat competition from offshore steel producers and competitive materials in a stagnant market. CANMET plays an important role in helping the steel industry but should increase its emphasis on identifying and focusing on the highest priorities and on facilitating the implementation of the technology, once developed. The benefits that will flow from the successful implementation of new technology in the steel industry will help both the steelmakers and CANMET.

FUTURE DIRECTIONS FOR CANMET

W.G. Jeffery and J. Kuryllowicz

Introduction

The Canada Centre for Mineral and Energy Technology (CANMET) directly assists the mineral and fuel industries of Canada by technology research and development. It is also a government establishment providing standards and certification services, scientific advice on policy matters such as acid rain to Ministers, and leveraging government funds to increase R&D in the private sector.

The efficient management of an R&D establishment requires a long time perspective with regard to the human resources and specialist skills that are available, as well as the identification of useful and relevant research work. There are many kinds of R&D with different goals with respect to time and risks. Even if the management and balance of these parameters is fully achieved, research is an activity where the effort is to achieve something as yet unknown. Therefore the outcome cannot be guaranteed; the project may fail to achieve its intended purpose or it may emerge with a result that was not planned or wanted. So how does one measure effective research? How does one measure efficient science? With so many performers, so many clients, so many critics, the performance of research is measured mostly in the eye of the beholder.

Nonetheless, governments should spend the taxpayers' dollars wisely, auditors must measure and report, and a science policy is requisite.

The three performers of R&D in society are universities, industry, and government-supported laboratories. Over the years there has been some sharing of knowledge between them but their goals and motivation have marked differences. In many respects, government laboratories operate in a central area, with research relations with both university and industry, often weighted to one or the other depending on the nature of the research. Table 1 shows an estimate of the sources of funds in mineral sector R&D.

In Canada, the recent changes in attitude have followed similar trends in the western world of increasing awareness of the importance of technology in national

Table 1

FUNDING AND PERFORMANCE OF R&D IN THE MINERAL SECTOR, 1983/84

Performers of R&D	% Share of R&D Performance	Sources of Funds ($ million)				
		Ind.	Fed.	Prov.	Other	Total
Industry	72	200[a]	10	4	4	218
Federal government	14	-	42	-	-	42
Universities	2	1	3	3	-	7
Provincial and other Canadian	11	12	1	15	6	34
Totals	100	212	55	22	11	301
% Share of total funds		70	18	7	4	

Note: these figures are derived from sources of variable reliability. Use with caution and for general comparisons only.

[a] 1983 preliminary (incl. fabricated metals).

industrial policy. An early sign of this awareness in Canada was the Report of the Task Force on Federal Policies and Programs for Technology Development, completed in 1984 by a small committee, largely of nonscientists, chaired by Douglas Wright. This report, completed swiftly and somewhat superficially, is nonetheless easy reading and achieved a fairly wide audience. With its general theme of change by providing more money to universities and less to internal government R&D in order to better serve industry, its message was noted by a new government that had committed itself to an increase in R&D and the strengthening of science policy. This was put into effect in 1984 by the appointment of a full-time Minister to the Ministry of State for Science and Technology (MOSST). Subsequently, the Nielsen Task Force on Program Review was active throughout

1985, and a large component of the work of the various Study Groups was targeted at the functions and operations of science departments in government. MOSST derived a mandate from the Nielsen Review to examine the operations of technology centres across the country, while the Natural Sciences and Engineering Research Council of Canada (NSERC) strived to extract more money for university research funding, and the National Research Council reoriented itself to the surprising cuts in late 1984 and the changing climate of science in government. (A Practical Perspective; the NRC Plan 1986-1990).

So there was a great deal of activity in Science Policy in 1985 and we are still in a time of re-evaluation and debate about research institutions and the respective roles of the three major performers.

In passing, it should be noted that similar processes have been under way in other parts of the world. In the United States the partial counterpart to CANMET, the U.S. Bureau of Mines, with whom we have had very close relationships through the years, had been buffetted by change, by reductions, and by direction to diminish greatly its historic closeness of service to the mining industry in order to concentrate on more basic, higher risk and longer term research. In the United Kingdom the science community as a whole has received severe cutbacks and some government laboratories have been either disbanded or privatized. In Australia there have been similar questions relating to the role, the accountability and the relevance of government research institutions.

CANMET Present

At this point, having set the environment of change in place, it should be noted that I make this presentation, not as a policymaker, but as a hands-on manager of a fairly large government laboratory that has, and always has had in my view, a pretty clear mission, a well defined set of customers and clients, and a generally pragmatic view that the job is to assist and improve the mining, metallurgical and fuel industries of Canada. By and large, with some errors and mistakes, some fumbled passes, I would argue that the outfit hasn't done too badly over the years since 1907.

So what is the problem?

It is the need for any organization to adjust to changing times and priorities, to new mandate and new perceptions; above all, to be seen to be accountable and relevant to the current society.

The history of CANMET is not relevant in this presentation except to note that during a time of change, of questioning, of ferment, it is frequently believed that new institutions, new structures and new rules are needed to cope with new demands, aspirations and conditions.

Therefore a long-standing institution is often suspect as entrenched, rigid, and unyielding. In policy-making the urge for change for the sake of change is pervasive. Perhaps there comes a point where an outfit has survived so long that it becomes nominated as a Heritage Institution!

CANMET's mission was renewed in 1983 by the federal government in the following terms:

> To enhance the role and contribution of minerals and energy to the Canadian economy by means of mission-oriented research and development in mining, mineral processing and utilization of metals, industrial minerals and fuels which:
>
> - provides information to the Minister for making non-renewable resource-related policies;
> - serves government social objectives for health and safety and the environment;
> - is supportive to R&D performed by industry in order to improve the economic performance and productivity of industry.

The above three principal mission goals of CANMET's R&D have been identified as Policy R&D, Protection Technology, and Productivity Technology.

In my view that mission statement stands the test of time and its fundamental aspects remain true despite the changing environment. The mission is sound but the changing times call for different ways and means of achievement, as well as a different balance between Policy, Protection, and Productivity R&D.

In managing any organization, the two main questions are what and how.

At CANMET, what it should be doing has largely been determined through contact with our clients, formalized by - but not limited to - the National Advisory Committee on Mining and Metallurgical Research (NACMMR), in addition to direction from our Minister. Government central agencies such as Treasury Board (TB) and MOSST influence the program direction, but their impact has been mainly to influence or limit how the program is carried out.

Given the call for increased and demonstrable relevance and responsiveness, a stronger and more effective

NACMMR influence is indicated: for example, a Board of Directors that reports to the Minister, or a stronger management advisory role to the Minister. Whether this can be achieved will depend partially on whether the other players will correspondingly decrease their direction and whether NACMMR itself can evolve to fill this role.

NACMMR functions at two levels. As the Main Committee it looks at the overall direction and priorities, and should be composed of people who are familiar with larger industry priorities, probably senior executives as well as representatives of the major associations that make up the industry. The five subcommittees have a different role - to evaluate specific projects not only as to their goal, but also how they will be or are being carried out. Is the work needed; is it sensible; is it outlined in appropriate stages; even if it is a novel high-risk and long-term approach, does it have merit; and perhaps most importantly, does the proposal appear to be reasonably cost-effective? The subcommittee thus should be composed of hands-on, knowledgeable professionals who can analyze not only the outcome, but also the efficiency and effectiveness of a project.

The individuals who serve on NACMMR have provided a valuable contribution to CANMET, largely because of their personal interest and commitment. Necessary for the future is an industry-wide interest and commitment; above all we must achieve awareness at the CEO level.

CANMET Future

Given this scenario of change and the need to recognize and respond to new priorities, let me try to present some of the conflicts for the hands-on manager in this role of research deliverer.

Clients and Customers

In many ways, the clients and the customers remain the same as always: namely, government itself, society as a whole, and the specific industrial sector that we serve. Each of these customers clearly has its own set of objectives and also tends to have its own type of research work that is undertaken on its behalf. The question for the research manager is always how to allocate resources to serve these clients, and in what order of priority.

Current government policy is that the industry comes first and foremost by far; indeed, some argue that industry is the only client because it is the private sector that

generates jobs and promotes the economy. Therefore responsiveness to industry needs, to demand-pull for new and improved technology, should be the sole criterion for the research manager. Certainly the emphasis for this need in the mining and metallurgical industry has been evident in the difficult recent years. CANMET responded to this circumstance in 1983 with a two-year program of partial resource diversion to Short-Term Assistance in Research and Technology (the START Program) in which almost 100 companies became involved.

But even the most hardy entrepreneur of the private sector acknowledges from time to time that the government has a purpose to foster research in such matters of safety, health, and the environment, and to provide standards and certification services to the community as a whole, including industry.

At this point, it is worthwhile giving some thought to the differences between private R&D and public R&D in terms of investment goals and expectations. These aspects can be compared on figure 1. The predominant issue that arises in any comparison relates to the timeframe in which R&D is done, but we can return to this later.

PRIVATE	PUBLIC
- Corporate competitive edge	- National advantage (especially for a trading nation)
- Competitive excellence	- Economics dictate need for national facilities
- Direct business investment (venture capital)	- Social goals; health, safety and environment
- Need for control and integrity of intellectual property	- Sovereignty considerations
- Limitations (inability) to share costs of high risk R&D	- Widespread generic R&D benefits whole industry/ society
- Short time frame to achieve return on investment	- Potential to aid small and emerging private sector firms
	- Leeway to pursue R&D goals over longer time span
	- stable R&D community to provide well of knowledge

Figure 1. R&D investment goals and expectations: comparison of private and public sectors.

To return to our current theme of clients and customers, it is abundantly clear that an essential criterion, whatever the debate on the effort to be distributed between different clients, is that for each and every one the work being done should be relevant to their needs.

But how does the R&D manager determine relevancy? Current policy-makers state that relevancy must be measured by the enthusiasm with which the customer will snap up the product. Furthermore, the enthusiasm will be revealed by the willingness to pay for the research work. If clients won't pay then the work is not worthwhile. However, every inventor or researcher becomes involved in identifying a potential product that has no client because the use has not yet been identified. In their time, the automobile, the telephone and the transistor struggled for existence.

Furthermore, the mining sector is one where upfront capital investment is immense. Consequently, it is an industry that is very conservative in introducing new methods and processes; it does not want its risk exposure to be too high. If times are tough, it wants no risk exposure at all on the technology side; it has plenty of problems with markets, prices and costs. On such occasions it is not in a position to pay for R&D, relevant or irrelevant, and demonstrates this sad fact by disposing of R&D staff as among the first to go. In the government laboratory, work done on health, safety and environment aspects is generally not that which industry requires and does not fall into the category of cost-recovery R&D. Therefore relevance measured by the willingness to pay is not universally applicable, but the R&D manager must recognize its importance as a measure of justification for a portion of an R&D program.

Technology Transfer

This leads to the subject of technology transfer, because commissioned research (demand-pull) inherently has a high chance of adoption. Many scientists have considered that technology transfer from bench to demonstration to commercialization is largely an evolutionary and almost automatic process that relates to the merits of the research and its place in time. The last ten years has seen a widespread realization that this is simply not true. Successful innovation requires unremitting effort and hard work. There are many ways in which the scientist can be assisted, encouraged and motivated to be an active and aggressive technology transferor. And for a public sector R&D organ-

ization such as CANMET, technology transfer can be said to be a bottom line - a measure of the effectiveness of taxpayers' dollars. It is essential that research findings be passed to the clients, whether they be other parts of government, the public, or the industry. This is why an Office of Technology Transfer was established in CANMET in 1981 because without that specific drive, that visibility, the science community will have a laissez-faire policy towards technology transfer. Scientists will participate in varying degrees depending on their enthusiasm and viewpoints regarding basic and applied research, but it will be haphazard and spasmodic. Without vigilant science management, opportunities for patenting and licensing can easily slip by, and the entire organization is therefore not operating efficiently.

Those who advocate demand-pull R&D that meets customer needs claim that if the customer will pay for the R&D, or will join in on the venture, then this is the best way to ensure technology transfer. The client already has a vested interest in success. And this is absolutely right. But if we take into account that there are other forms of R&D, the technology-push, the innovative, the long-term, the high-risk, the curiosity-motivated research, leading to the new discovery, the unforseen or spin-off results, then mechanisms for technology transfer are important. The manager's job is to ensure that every effort is being made.

The differences between demand-pull R&D and technology-push research are illustrated in figure 2, which was developed up by a large private sector R&D laboratory. It is interesting that this organization, which has an excellent record of major and minor research successes over a long period of time, considers that both types of R&D are vital. They noted that there were fewer technology-push successes, as would be expected, but that the average monetary return on any one success in this category was considerably greater than the demand-pull research requested by the production departments of the company. In other words, if you care to take the risk, there is a bigger pay-off in building a new mousetrap than in improving the old one.

Government laboratories have a role, for a portion of their effort, to try to build new mousetraps. There are those in the private sector (the customers, not the competitors) who clearly believe that such work should be a major component of government laboratories. Their view is that government research is being supported by corporate taxes and therefore this higher-risk generic research is indirectly supported by industry for its own good. Indeed, these

MARKET PULL PROJECTS	TECHNOLOGY PUSH PROJECTS
- Clear-cut objectives	- Goal often unclear
- Good sponsor support	- More skeptics than sponsors
- Some success almost certain	- Long time horizon
- Keeps the business rolling	- Success unclear until near the end
- Gives research a good image with the business	- Commercialization often very difficult
- Seasoned professionals involved	- Benefits from successes are large
	- Often a young man's game

Figure 2. Comparison of market-pull and technology-push R&D projects

clients are those who object strongly to paying full cost-recovery rates for facilities that they consider have already been established by their tax contributions. Although they argue that government should not be in short-term research, it is a fact that a considerable capability for short-term research response stems from a larger base of long-term R&D effort. It is often the expertise and facilities that accompany the "far-out" R&D that provide the capability to respond to short-term demands with great effectiveness and efficiency.

Whatever the nature of the R&D effort, whether there is an industrial partner or not, the need to visualize and to plan technology transfer at various decision points in the project is an essential part of managing a research organization.

Contract Research and Cost Recovery

An individual company can choose to have its own research engineers and facilities, but clearly this can only be effective for big companies. Only a few of the larger Canadian mining and metallurgical corporations have gone this route. Smaller firms cannot afford or do not have the consistent need for company research staff; they can seek the services of consultants, private sector R&D organizations,

or provincial or federal laboratories on a contract basis. Universities perform their own research, closely linked with the teaching process. The government laboratory has the freedom to send out some washing as well as take some in, and also perform its own research. Indeed, for quality control of contracted research, it is essential to have quality in-house scientific expertise. So the manager has a blend of actions in the allocation of resources to contracting-out, contracting-in, and in-house R&D. I would not consider it prudent to operate in one mode alone to achieve the complex objectives required of public sector R&D.

This government wishes to optimize the contracting out of research requirements. This results in more work done by the private sector, based on the lowest price tendered and therefore done most efficiently. But there are occasions, research being the achievement of the unknown, when operating on the basis of the lowest bid is a debatable procedure in obtaining value for the contract dollar. However, more contracting out also means less in-house research, with an appropriate reduction in the number of scientific public servants.

To reinforce the point recently made, efficient contracting out can best be achieved when there is a strong in-house capability to perform sophisticated R&D of an equivalent nature to that being bought. The same principle applies to all funding support by government for private sector requests for technology development or demonstration. One may ask what about funding support for university research, but there is a most important difference. University research is supported by upfront money evaluated by peer review at the front end; there is not, as far as I know, a formal mechanism to review the results to evaluate the return on the dollar, or even whether the work was effective and valid. Nor should there be. The peer review mechanism for ongoing or subsequent funding soon senses the poor researcher and the chances of future success.

Contracted-out research is quite different; the results are wanted to augment other knowledge or for some specific application, and the work must be judged for quality, value and use.

At the same time, the government wishes to maximise cost recovery by federal laboratories for services rendered. These are services of a nature that it is a government role to supply such as setting standards, certifying products and the like. Also, each government laboratory has unique national facilities (e.g. the wind tunnel at NRC, the foundry facilities at CANMET) as well as top scientists

in their field. All these are special capabilities to respond to public needs or information.

There has always been a dilemma as to what to charge for such services. In the first place, in any government laboratory there are overheads for government-type research such as in environment, health and safety, or for data collection and dissemination, that would not be found in an equivalent institute in the private sector. If a research project is contracted in by a government laboratory, should the overheads of all other activities be charged? Secondly, it is not the intention of the government to compete against private sector R&D organizations. Thirdly, how should ability to pay influence cost recovery for services?

As the drive for increased cost recovery takes place, the pressure on managers and scientists is to do the work or solicit in-house R&D that attracts the private sector funds, which of course achieves the target of relevance and service to industry. It also promotes competition with private sector R&D organizations and to some extent negates the contracting-out policy emphasis. Increased cost recovery for R&D services will tend to shift the balance of short and long-term research towards an increase in short-term work. The historical role of government R&D has always been regarded as being in medium to long-term work; indeed in recent years the USBM was instructed to virtually vacate the short-term field work, and get back into the laboratory to do fundamental research.

The payment for a service or for a short-term company-specific research project is fairly straightforward. However, for longer-term generic R&D, it is difficult for any one company to justify financial contribution. Often results cannot be protected from competitors, and if they can be protected, is the government justified in contributing to results which will not be available to all potential users at a reasonable cost? CANMET will have to deal with these issues: should a project be blocked because not all potential users are willing to contribute? What is a fair share for each contributor? What is reasonable cost of access?

The manager of the government laboratory is a money-maker (increase cost recovery), an R&D performer (the knowledge base for government actions) and a funder (increase contracting-out). One might consider these roles contradictory, and yet, in many respects, one set of operations cannot be done adequately without the other; all are interdependent for a truly efficient role in basic and applied short, medium and long-term research.

Industry/Government/University Roles

As mentioned previously, there are three performers of R&D, and to some extent they have operated in their own solitudes, although this should not be taken too literally because it is evident that many individual examples of co-operation could be cited.

The government is anxious to merge the efforts of these R&D performers, with a declared objective of meeting industry needs with demand-pull research, of obtaining greater relevance to the economy from academic research, and to get a better return for the support dollar invested. There is also the hope that private sector funds can be leveraged into joint venture R&D, and that some of these funds will be invested to assist longer-term, more basic, research. The most recent government thrust to assist these marriages is the recent budget announcement concerning future funds through NSERC to the universities, providing there is equivalent private sector money on the table. In government laboratories, reduction in core funds to be substituted by private service money is requested; substitution of public service scientists by company engineers on secondment to the laboratories is desired.

It is clear that these incentives and directions to merge the three performers is a desirable and necessary policy. Each has its place in a total national R&D performance, each has its niche, but also each complements the other and the stronger the interchange, the healthier the nation's science base and technology development.

Conclusion

To sum up, this is a time of significant change in Canadian R&D, sparked by aggressive policy moves in the federal government. However, it would seem that the government policies are reflecting a broader change in attitudes derived from a variety of sources that relate to R&D management.

Peter Drucker, in his latest book on "Innovation and Entrepreneurship", has argued that we are on the move from a managerial to an entrepreneurial economy. "The entrepreneur always searches for change, responds to it, and exploits it as an opportunity".

The R&D manager is always reviewing potential change in the very outputs of the R&D organization. Too much planning is inconsistent with innovation. Part of a government R&D manager's problem is that the overwhelming emphasis and complexity of planning in government has to

be done and is what he or she is held accountable for, rather than results.

Tom Peters, of "In Search of Excellence" fame, has recently said that, in setting out to look for a system or a management manual that made companies stand out, he ended up with the realization that those successful organizations did no more than identify their customers' needs. Peters went so far as to say that he had no time for management, nor for markets; the emphasis must be on clients and customers because it is they who buy the product.

So there are winds of change in technology development and management.

What are the future directions for CANMET and the issues that must be dealt with?

Direction	Issues
Relevance and efficiency: these are the watchwords	- An improved Advisory Board that does, and is perceived to, represent industry. - Room for continuation of ad hoc, project specific committees. - More business and market plans.
Flexibility to shift resources: this is a hope	- Will government central agencies seriously consider MOSST endeavors to provide incentives to government technology centres?
Shorter-term R&D and technology delivery: realism dictates this direction	- Avoid hampering development of private sector R&D. - Will wither without minimum core of longer-term generic research. - Carefull balance is essential in a dynamic process.
Cost recovery (fees for service, contracting-in, joint projects): more is needed	- How much overhead. - Competition with existing or potential private sector. - Should ability to pay be a factor?

- Balance of cost and benefit among contributors to joint projects.
- Canadian interests versus revenue from foreign customers.
- Protection of proprietary information.

Contracting-out: more is needed

- Lowest bid versus effectiveness.
- Capability to manage.
- Conflict of interest potential with the Advisory Board.

As Drucker said, the service institution tends to maximize rather than optimize. This we must avoid, and the contribution of you, our clients, through this and other forums, is essential.

THE ROLE OF CANMET

Peter Richardson[1]

Introduction

The Canadian mineral industry is in urgent need of new technologies to increase its productivity and cost competitiveness in the face of stagnant demand and, in the case of many minerals, over-supply. The Canada Centre for Mineral and Energy Technology (CANMET) is potentially a major source of these new technologies for the industry. CANMET's operating budget is now in excess of $70 million, and its programs cover the entire range of minerals activity in Canada. Its spending is roughly divided equally between energy-related and non-fuel related sectors.

CANMET's mission is to enhance the role and contribution of minerals and energy to the Canadian economy through carrying out research and development which:

1. provides information to the Minister for making nonrenewable resource related policies;

2. serves government social objectives for health and safety and the environment;

3. is supportive to R&D performed by industry in order to improve the economic performance and productivity of industry.

This paper examines CANMET's role with respect to its non-fuels activities in mining, mineral sciences and physical metallurgy. This examination will be principally concerned with the overall stategic thrusts of CANMET in this sector, and its relationship to the Canadian mineral industry, rather than the technical characteristics of its activities, although the balance of its technical portfolio will be considered.

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1. The author wishes to acknowledge the financial assistance of the Ministry of State for Science and Technology and the Department of Energy Mines and Resources in the preparation of the report on which this paper is based. Views expressed are those of the author.

CANMET's role will then be discussed in terms of the stated concerns and perceptions of a sampling of executives in the mineral industry. A survey carried out during the preparation of this paper among key executives with technological responsibilities in the Canadian mineral industries showed that, for the most part, they do not perceive CANMET to be carrying out the third part of this mission effectively, and argue that the first two elements of the mission could be obtained at lower cost in other ways. Some of these executives argue that federal government funds currently allocated to CANMET could be used differently to assist the industry in these key areas of technology.

Reference will be made to the growing body of literature on management and technology which can provide insight into CANMET's performance. A review of options available to CANMET and the government which would address industry concerns will be provided, and recommendations made as to which of these appear practicable and preferable.

Industry Perceptions of CANMET

As part of the preparation of this paper, a short survey was made of twelve executives in Canadian nonferrous mineral firms, to ascertain their views on CANMET and its performance. The questionnaire used for this purpose is shown in appendix A at the end of this paper. Nine of these executives were responsible for technology or for research and development in major integrated Canadian metal producers. The other three were drawn from several sources including smaller firms and service corporations. A number of the respondents had served on CANMET's National Advisory Committee on Mining and Metallurgical Research (NACMMR) or its subcommittees. Together, the firms these executives represent account for more than 60 percent of the nonferrous mineral output in Canada, and probably over 90 percent of the research and development carried out by the industry.

There was almost unanimous agreement that CANMET was not providing the Canadian mineral industry with effective support, especially considering the resources available to it. A majority of executives stated that, unless the organization's strategy was changed significantly, and its effectiveness substantially improved, it should be closed down, or greatly reduced in size.

A major area of concern was CANMET's program strategies. The prevailing view was that work in CANMET was determined more by traditional areas of work and by the interests of the people in the organization than by the future needs of Canadian industry. It was felt that work often duplicates, rather than supports, that being carried on in corporations. The NACMMR committees were perceived as not having enough influence either on the selection of strategic thrusts or on priority setting. One executive stated: "CANMET consults with us, and then goes off and does exactly what it wants to do". Better program and project selection procedures were viewed as essential by most executives interviewed.

A second area of concern was the quality of the work carried out within the organization. There was general agreement that CANMET has a few outstanding researchers, but that the overall quality of effort and output is low, in terms of its impact on the industry. Executives perceived that joint work with CANMET was risky, in part because there was little influence over who within CANMET worked on the project. This concern was characterized by the following statement:

> There are a few people who are in great demand, and give excellent service, but more commonly, CANMET personnel don't understand our needs, or our time constraints, and are not results-oriented.

Asked to rate CANMET's overall effectiveness on a scale of 1 to 10, given the resources available to it, most executives rated it between 2 and 3, with a high of 5.

CANMET's physical facilities were highly regarded by industry executives, but they were concerned about their ability to gain access to them, and to utilize them on projects of significance to their corporations.

CANMET's relationship with the mineral industry was a third major source of concern to executives. This concern had a number of dimensions, including:

- the organization's willingness to take industry advice on its program of work;

- CANMET's perceived lack of ability to commercialize new technologies;

- the time frame of its technical development program;

- CANMET's relationship (or lack of it) with smaller mineral enterprises that have no research and development, and limited technological resources.

The Office of Technology Transfer within CANMET appears to be responsible for technical-economic studies, and for encouraging transfer of technology to Canadian industry. However, this department's budget is small, and its effectiveness was questioned. The responsibility for commercialization of new technology by CANMET is not sufficiently well defined according to industry executives.

Problems with CANMET's Present Strategy

Problems facing government laboratories have recently been examined in considerable depth in the United States in the "Packard Report",[2] and in Canada by the Task Force on Federal Policies and Programs for Technology Development.[3] These reports, although different in scope, both suggested that research and development programs in government laboratories were becoming increasingly irrelevant to the needs of industry, and that a "market-pull" mode of innovation should replace the prevailing "technology-push". As will be seen, these comments characterize in a general sense many of the specific problems facing CANMET.

CANMET seeks to implement its mission by devoting most of its resources to implementing a classical research and development strategy. Approximately three quarters of this work is carried out internally, and the remainder is contracted out to universities and private industry, primarily in Canada. In addition to this activity, relatively small amounts of its operating budget are allocated to technical information services, including industrial intelligence.

This in-house development approach contrasts sharply with a broader view of the role of research and development which is now gaining wider acceptance within industries, particularly those that are mature, and where innovation is arising from external sources. Potential roles for research and development can include the following:

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2. "Report of the White House Science Council", Federal Laboratory Review Panel, Office of Science and Technology Policy, Executive Office of the President, (The Packard Report), Washington, May 1983.
3. "Task Force on Federal Policies and Programs for Technology Development", A report to the Honourable Edward C. Lumley, Minister of State Science and Technology (The Wright Report), Canada, July 1984.

- innovation;
- create and extend scientific knowledge;
- gatekeeper for new technologies;
- technology transfer;
- industrial intelligence;
- data bank for scientific and technical knowledge;
- technical assistance and service;
- consulting;
- establish links to the scientific community;
- recruit and develop scientists and engineers for the corporation.

In this mode, research and development acts as a gatekeeper for new technologies, whatever their origin, and transfers these effectively into operations.

CANMET's budget for mineral-related activities, amounting to just under $40 million, is allocated across a broad spectrum of activities including mining (approximately 20 percent), mineral process (50 percent), and metals and materials (30 percent). Given the scope of these activities, the large number of projects under way, and the resources required to commercialize such technologies, there are doubts about the ability of CANMET to commercialize developments within a reasonable time frame.

There is general agreement that the financial and human resources required to commercialize significant new technologies for the mineral industry grow exponentially, becoming very high in the design and demonstration phases.[4] Unless these stages are undertaken effectively, the technical risk in new developments is too high for commercial adoption by industry, and the technology is likely to "stay on the shelf". The executive's perception of its poor track record of major innovation suggests that CANMET pays insufficient attention to the importance of these later stages in innovation, fails to make the hard choices on which technologies to pursue, and does not allocate sufficient resources to design, demonstrate, and implement new technology.

In addition to internal constraints, CANMET also faces significant barriers to technology transfer between itself and the industry. Morton, a vice-president of Bell Laboratories during its most productive era, has argued that in-

4. Gian F. Frontini and Peter R. Richardson, "Design and Demonstration: Critical Functions in Industrial Innovation" Sloan Management Review, Fall 1984.

novation will be the exception rather than the norm if geographic and organizational barriers exist between supplier and user of new technology.[5] CANMET faces both types of barrier, since its main facilities are located in Ottawa away from mining centres, and, as a government establishment, its goals are quite different from those of the corporations it should serve. A majority of executives questioned in our survey rated CANMET's linkages to mining firms 2 or 3 on a scale of 10.

A major exception to this prevailing view, but one that reinforces the point above, was that of an executive from a company with operations in the Elliott Lake area. He found that CANMET staff at the Elliot Lake facility were interested in his company's problems, helpful, and provided a timely response.

CANMET also suffers from a lack of sponsors in Canadian corporations for its new technologies. Roberts and Fusfeld identified one of the key roles in innovation as that of the sponsor who is committed to the new technology, and willing to commit resources to ensure it is implemented.[6] CANMET's prevailing mode of operation, which is often relatively independent of industry involvement, rarely allows this role to develop except for situations in which industry executives have funded specific projects in CANMET's laboratories.

The focus of CANMET's technical activities can also be questioned. Mining enterprises make up the bulk of establishments in the Canadian mineral industry, and are responsible for the majority of investment and costs incurred. However, within its mining budget, only about 10 percent of CANMET's effort, less than $1 million, is allocated to mining equipment, an area which as been identified as having great potential for safety and productivity improvements.

Recognizing a similar imbalance in their own technical activities, a number of integrated mining companies, most notably Inco, have developed stronger mining research and development programs in recent years. There is also a general industry agreement that more needs to be done in this area. CANMET's strategy does not yet reflect this awareness of the critical importance to Canada of improved mining technology.

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5. J.A. Morton, Organizing for Innovation, New York: McGraw-Hill Inc., 1971.
6. Edward B. Roberts, and Alan R. Fusfeld, "Staffing the Innovative Technology-based Organization", Sloan Management Review, p. 19, Spring 1981.

Compounding these strategic and structural factors inhibiting CANMET's effectiveness are a number of perceived shortcomings in the organization's internal culture which limit its ability to commercialize its inventions. These include a bureaucratic management style and financial reporting requirements which promote risk avoidance and administrative excellence, rather than encouraging outstanding scientific and engineering skills and achievements. While these shortcomings are hard to measure (and by no means unique to CANMET), they are also reflected in informal comments and observations of CANMET staff, some of whom perceive promotion as coming more from political adroitness than from quality of work.

In a similar fashion, the allocation of funds is criticized by industry executives as favouring established programs and projects, rather than being based on technical relevance and future importance. This tendency is felt to be due in part to CANMET's unwillingness to eliminate its scientific and technical "deadwood", a problem it shares with many government laboratories. As a result, more promising activities are underfunded and take longer than necessary to commercialize.

Alternative Strategies

The Canadian mineral industry needs a stream of major technological innovations to drive its long-run competitiveness. For a variety of reasons, little of this work is being done in corporations in the industry at the present. Generally, research and development activities are focusing on short-term needs aimed at improving current profitability. The precarious financial position of many of Canada's major mining corporations constrains spending on long-term work to minimal levels.

Government funding for such long-term work, relatively free from short-term profit pressures, is desirable; however, the work must be relevant to the future needs of Canada's mineral corporations, and there must be some likelihood of future commercialization of the results. At the present time, some key executives in the Canadian mineral industry appear to be extremely sceptical of CANMET's ability to deliver on either criteria.

A major move which some mineral industry executives favour would be to separate the energy sector activities from the mineral sector. Since the technological overlap between these areas is relatively small, the merging of the two research streams in one organization appears to be a

marriage of bureaucratic convenience. Given the federal government's recent preoccupation with energy, it is likely that minerals sector activities have been of less concern to senior government officials.

Dealing solely with CANMET's mineral activities, a variety of options appears to be open to the federal government to increase the likelihood of technological relevance and commercialization from the activities which it funds. Essentially, these are variants of three basic choices.

1. Continue with CANMET in its present form, modifying its strategies, policies, and governance to make it more relevant and effective.

2. Discontinue CANMET as a federal government agency, but reorganize it as the nucleus of a joint private-public sector technology agency.

3. Disband CANMET completely, placing many of its facilities and key research staff either in Canadian universities or in mineral industry corporations, and redirect federal government funding to these institutions.

Each of these alternatives has advantages and disadvantages, as will be detailed below.

Continuing with CANMET in its present form is the simplest option to implement. In this form CANMET could continue to fulfill the first two elements of its mission as at present, and changes could be made to improve the effectiveness with which it implements the third element, support of industry R&D.

To be successful, these changes would have to include a clear definition of CANMET's role within the Canadian mineral system, and would likely lead to a much broader mandate than at present with respect to technology. In particular, CANMET could be expected to:

- provide a more extensive and effective technology intelligence network for Canadian mineral firms, and be proactive in this role;

- change the balance of its activities to include more mining related activities and product development;

- develop and implement an "extension program" service, to assist smaller mining enterprises that have limited

technical resources in the adoption of best-practice technologies;

- increase the amount of work and internal resources aimed at key peripheral technologies, such as process control and robotics;

- place more emphasis on commercialization of technology and less on generating new knowledge.

Such changes would require considerable changes to CANMET's mode of operation, program mix, and balance of skills. To develop and maintain a more relevant program, more input and possibly control from private sector institutions would be required. To maximize the likelihood of technology adoption, sponsors and clients in private sector corporations should be identified at the outset for work that is destined to end up in commercial use. Most likely, more of CANMET's operations would be decentralized to facilitate the later stages of development and commercialization through close working relationships between scientists and engineers in CANMET and private sector firms.

Government agencies have poor track records for implementing such radical steps to change themselves. Government managers have little personal incentive to bring about change on such a scale, and the social and political tensions that are created by such change inevitably bring it to a grinding halt. In addition, the climate and motivational changes required inside CANMET to provide staff with the incentive to implement the mission would be substantial, and difficult to implement in a government agency.

At the other end of the spectrum, under option two, CANMET could be significantly down-sized so that it would continue to perform the first two parts of its mandate, with respect to safety and health and providing the minister with information, but lose its mandate for performing other types of R&D. Much of its existing research and development resources could be disbanded, some being moved to private sector organizations, and others to universities. A small staff group could then manage a budget for contract research and development intended to achieve the same outcome as today's programs inside CANMET.

Option two has several attractive features. First, it would almost certainly be more flexible than today's activities in CANMET, which are influenced by the existing mix of staff and their interests and capabilities. Second, there is a much greater likelihood of technologies being commercialized, especially if the later stages are carried out in mining firms themselves.

There are, however, a number of drawbacks. Most important would be the reduced likelihood of proactive, comprehensive technology transfer across the mineral industries. Larger firms with R&D facilities would almost certainly gain more than smaller mining enterprises. Second, technical property rights for major innovations could be problematic. Finally, there would still be no guarantee that the parallel technical development process which needs to occur to rapidly drive technology into the industry would be obtained.

The third option would bring together the federal government, the private sector, and universities in a united approach to technology for the mineral industry. In this approach, CANMET would become the nucleus for a new organization which, besides carrying out and managing major technical development programs, would be responsible for the implementation of a technology strategy for the mineral industry in Canada.

This organization would be an integrative technology organization which would bring together technical development activities in universities, government agencies and the private sector in a national technology strategy for the industry. Its activities would encompass all those previously outlined under option 1.

Direction and funding would come jointly from the government and private industry, with the private sector making much of its contribution "in kind", through, for example, the use of facilities and personnel. Most of the work would be on a joint venture basis, actively involving mining equipment manufacturers and companies from other sectors in its activities. Much of the longer-term research would be contracted out to universities, which would also be represented on the board.

In the longer term, major regional laboratories could be established in regional mining centres such as Sudbury and Timmins. These regional centres would be the focus of the technology transfer thrust, through the management of design and demonstration projects for major new technologies, and also through the administration of a vigorous technology extension program, aimed at transferring proven technologies to smaller mining enterprises.

Concluding Comment

At present, there is a growing consensus that there is a need to forge a technical strategy for the Canadian mineral industry. There is also widespread agreement that a co-

operative, integrated approach should be adapted. The challenge facing Canadian mining executives and their government counterparts is to translate this awareness of the problem and the vision of what might be into tangible, implemented strategy. Canada does not have a good track record in such matters. At present a window of opportunity exists to make the vision a reality. Failure is likely to mean continuing decline. Success will contribute substantially to a continuing, viable mineral sector which will enhance Canada's position as a leading international trading nation.

APPENDIX A QUESTIONNAIRE CONCERNING CANMET
(administered by interview)

1. Does your organization have any studies under way jointly with CANMET at the present time?
   a) If no, why not?
   b) If yes, are you satisfied with the outcome?

2. Please assess CANMET's purpose and balance of work;

   i) Balance between
      a) ferrous metals
      b) nonferrous metals
      c) energy

   ii) Time frame
      a) long term
      b) short term

   iii) Within ferrous metals
      a) mining
      b) metallurgical
      c) other

3. What do you view as CANMET's strengths and weaknesses at present?

4. How do you view the strengths and weaknesses of CANMET's linkages to the mineral industry?
   Rank from 1 (very weak) to 10 (very high).
   Discuss.

5. Assess CANMET's current effectiveness compared to the resources available to it.
   Rank from 1 (very low) to 10 (very high).
   Discuss.

6. How do you feel CANMET's effectiveness can be improved?

7. What is your assessment of the relevance of CANMET's work?
   a) Now
   b) In the future

8. What type of work should CANMET undertake?

COOPERATION IN THE NICKEL INDUSTRY

J.P. Schade

Introduction

In 1927, Henry Ford - the man who put America on wheels, an engineering genius with a warm feeling for his employees, (he operated a profit-sharing plan in the 1920s) - faced a disastrous situation. He had mass-produced more than 15 million automobiles of the Model-T series, lovingly called the Tin Lizzy, when he had to stop his assembly lines for a whole year. Unsold cars were piling up at the plant and in dealerships.

Ford had thought he could serve the market well, at a competitive price. It is a little heady to note that the Tin Lizzy sold for $500 in 1913! His product had earned a solid reputation in almost 20 years of performance, and it was affordable to millions of Americans.

Nevertheless, Henry Ford failed.

He failed because he did not appreciate the dynamic character of the marketplace. He persisted in offering a car "in any colour provided it was black", while his competitors lured customers away by offering a variety of colours, new technical concepts, more comfort, stronger engines and so forth.

History informs us that Henry Ford and his company survived that competitive battle and, after a year of hectic transition, he started to produce a more modern automobile. But his adjustment to market demand was too tardy to prevent him losing his position as number one in the auto industry to General Motors.

There are umpteen similar examples in the history of modern technology that demonstrate, quite clearly, that an industry might easily go the way of that magnificent bird the dodo, if it is not ahead of technological change and market forces.

Why would Singer stop producing sewing machines? Why would International Harvester no longer produce farm tractors? Or, can you imagine what serious decisions would confront you today if you produced mechanical or electrical typewriters, or carbon paper, at a time when wordprocessors and photocopiers are taking away virtually all your business?

Safeguarding End-use Markets for Nickel

The marketing horror stories I have cited, and I am sure they were not new to you, have one common denominator: to produce something in the hope that there will always be a market for the product can be fatal. On the contrary, we must defend the products we produce in their existing applications, and we must find new applications, by early recognition of upcoming changes or trends in technology and in consumer fashions. Only in this way we can position our products in such a way that they can serve future demand.

If we were involved in the production of consumer goods, anything from electric appliances to cosmetics, it is clear that exploration of consumer behaviour and fashion trends, product innovation and promotion, advertising and the like would be a vital part of our daily lives. In producing raw materials from natural resources, however, our industries carry a tremendous handicap, as in most cases we are several steps away both from the decision-makers that decide the future demand level for our products as well as from the end-use industries that are the ultimate consumers of materials containing a small percentage of what we produce as our main product.

For example, can a producer of iron ore exercise an influence on the people who decide whether future automobiles will be built of steel or of plastics? Can a nickel producer prevent the erosion of the market for stainless steel kitchen sinks? Can manufacturers of copper save the market for automotive radiators against the inroads made by aluminum? I think the answer is yes, provided we have sound technical arguments on our side, activate our research and development capabilities, and do not consider substitution as our fate.

Unfortunately, it is also true to say that companies in the nickel business in the recent past have seen more embarrassing events than good news. For example:

- the price of nickel has had its ups and downs, recently more downs than ups;
- new producers have entered the scene, while others, like Amax, have exited from the stage;
- governments have become more and more involved, sometimes rescuing financially weak producers, and now hold ownership of a substantial part of nickel production worldwide;
- the communist bloc has become an extremely serious and sometimes highly aggressive competitor.

On the positive side, however, the nickel industry has in the past five years gone through a cost reduction exercise that has shown impressive results in terms of increased productivity and reduction of operating costs. But what has happened to the demand side of the equation?

If one sits back from the hectic activities of day-to-day business and looks at the overall situation of the nickel industry (or, for that matter, at any other mature raw materials industry like the copper, chrome, silicon, and manganese businesses), one discovers that some of the fundamentals in our business do not seem to be right. This is true, in particular, when we compare ourselves to more modern and prosperous industries.

Look, for example at nickel consumption over the past 30 years, and then the last 10-year period as shown in figure 1. This picture, however, hides the fact that we could hold the zero growth line only because growth in the developing world has compensated for negative growth rates in quite a number of industrialized countries such as the United States, the United Kingdom, Sweden and France, just to mention a few.

The second fact is that nickel, and copper also, has been left behind in the race for top honours in the materials competition that is taking place in today's technology. Plastics and fibre composites still enjoy substantial growth. Aluminum, although it seems to have reached a plateau in terms of consumption, shows consistently higher growth than nickel-containing materials. More modern substitutes like ceramics have made their entry, but are not shown on figure 1 as no reliable statistics exist so far. Clearly, the threat to nickel is substitution. The question remains: How can it be prevented?

Let me also mention, as my third observation, that both the nickel-producing and nickel-consuming industries, under the pressure of bad times, have reduced their applicational research budgets, their market development efforts, and their promotion programs. It has happened in all countries worldwide, with the possible exception of Japan. Please understand me: I am in no way expressing criticism, I am just trying to explain what might have contributed - apart from oil shocks and lack of investment - to the scenario in which we find ourselves today.

The Nickel Development Institute

In recognition of this dangerous situation, nickel producers formed the Nickel Development Institute (NiDI) in the mid-

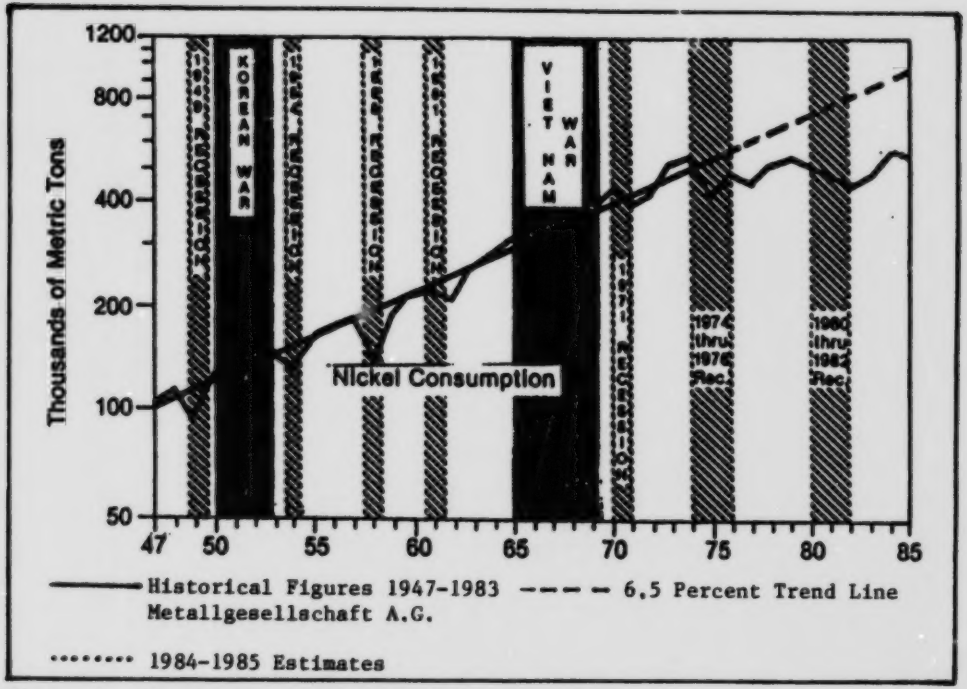

Figure 1. Non-Socialist World Nickel Consumption

Nickel Development Institute, October 1985

dle of 1984. Defined objectives are necessary but it is abundantly clear to all of us at NiDI that the ultimate success or failure will be measured quantitatively in terms of new nickel markets created and substitution losses prevented. We have therefore made an attempt to evaluate what quantitative impact our programs and related activities might have on the nickel consumption pattern over the next five years. This exercise is based solely on the projects we have implemented so far. With the initiation of further development and research plans and the expansion of our activities into areas not yet approached, our chances of success will, of course, improve.

We have become active in a selected group of end use industries: the marine industry, which had a negative growth-rate over the last ten years; the electronics industry; building and construction; and the principal capital industry group (chemicals, process, power and petrochemicals). These industries represent a primary nickel consumption of over 440 million pounds per annum or a good third of the total western world consumption.

According to our estimates, the market development projects implemented so far will account for an increment of some 35 million pounds per year by 1990, or an increase of some 58 percent over the natural growth expected otherwise.

How then is the Nickel Development Institute active in the market? Let me first explain the three basic types of projects we undertake:

- market development projects
- market exploration projects
- research projects

We assume that, in the long run, some 80 percent of the funds available for project work will be spent on direct market development and exploration with some 20 percent on research supporting market development.

Table 1 shows a breakdown of the 1984 total western world end-use of nickel. We have implemented market development projects and established targets for each of the industries marked with an asterisk in the table. We have started exploration work to establish whether or not it is worthwhile to proceed on certain other projects.

Table 1

WESTERN WORLD END USE OF NICKEL, 1984

End Use Industries	Percent of Total Consumption
Consumer products	25.4
Construction equipment and machinery	13.5
Automotive	10.5
Chemical*	8.8
Building & construction*	6.4
Process*	5.7
Electronics*	5.5
Power*	5.4
Petroleum*	5.1
Aerospace	3.3
Nickel chemicals	2.3
Coinage	1.6
Marine	1.6
Other	5.0

Source: H.H. Pariser Study, 1985.

* Industries for which NiDI has implemented market development projects.

Projects

I referred earlier to one-third of the end-use markets for nickel where we have implemented projects already. In total, we operate in this, our first fiscal year, 29 projects in market development, market exploration and research. They cover enormous ground, from engineering workshops for materials over SO_2 scrubbers to marine-related materials, coated stainless steels for roofing and side-walling. It would consume substantial time to take you superficially through all of the projects. Let me therefore just mention a few examples of how we approach market development.

We have completed seven engineering workshops on the U.S. east coast with well-known engineering companies. A team of four NiDI consultants discussed, with material specialists of the engineering companies, material selection for particularly severe heat and corrosion conditions. The program was subsequently taken to Toronto and Sudbury and later this year we will be in Europe and on the U.S.

west coast. A truly hands-on approach to market development.

Promoting and defending markets for metals is an international pursuit. Basic to the success of the undertaking is cooperation between national industrial associations and the Nickel Development Institute. In this regard, working relationships have been established across national borders and oceans separating continents.

A specific example is NiDI cooperation with the American Iron and Steel Institute on a collection of case studies about the life-cycle costs of materials in flue gas scrubbers for SO_2 removal. The booklet will be available by June 1986 and will, it is hoped, help to convince future operators of scrubbing systems - in Europe, Japan and elsewhere - that nickel alloys are the better choice for performance in this terribly aggressive environment.

The stainless steel sink is the largest individual application of nickel stainless steel, consuming about three percent of all austenitic stainless steel produced in the world. Unfortunately, new materials promoted by the chemical industry (marble imitations), as well as the old enamelled steel sink, are tough competitors because they offer colour as an option. We have recently completed a study on the present European situation, which unfortunately showed that the market is fading away faster than we had believed. Shortly, we will make the study available to our contacts in the steel industry and to the sink manufacturers with the objective of developing a rescue plan for the stainless sink.

Just another example, this time from the research end of our activities - zinc-nickel plating. Let me explain the background. The objective is to develop a process for zinc-nickel plating of small components based on the use of metallic anode material.

Zinc-nickel alloy electroplating, a new market, is the most promising market for nickel that has come down the pike in recent years. Believed to consume about 500 tonnes of primary nickel per year in the Japanese auto market, zinc-nickel alloy electroplating has the potential to consume 20,000 tonnes of primary nickel (44 million pounds) annually by 1995. The ultimate potential could be as high as 55,000 tonnes or 120 million pounds a year.

This NiDI project will provide the capability of improving corrosion-resistance of small electrogalvanized parts, particularly automotive and appliance parts, to the same extent that the corrosion resistance of electrogalvanized steel sheets has been improved by the co-deposition of zinc and nickel in a continuous process developed in Japan.

The action plan called for a two-year program to develop a practical batch plating system and to study the mechanism of co-deposition of zinc and nickel to enable optimum control of the process under normal industrial conditions.

Services

In recent years, the nickel industry has not disseminated any promotional literature, magazines, newsletters or the like. In an effort to make up for their absence, the Nickel Development Institute has initiated a number of services for the nickel-producing and consuming industries, with the production and dissemination of an in-house magazine being a high-priority item. The first three editions of Nickel have appeared. The Institute publishes this full-colour journal on a quarterly basis. The target audience includes decision-makers in engineering design firms, architects, consultants and designers, university professors, students and so forth.

Nickel carries news on modern applications of nickel-containing steels and alloys cross-fertilizing ideas globally among fabricators and manufacturers of nickel-containing products. It serves as a useful reference and as educational material in universities, colleges and technical libraries. It also is aimed at increasing public awareness with respect to the special advantages of nickel steels and alloys. The Institute circulates some 15,000 copies of each issue.

Furthermore, staff and consultants of the Institute have presented nickel application-related papers and lecturers at congresses and industry meetings, and will continue to do so. The preparation of data sheets for various end-use industry sections, and a Corrosion Atlas for worldwide distribution later in 1986, are envisaged. We also have subscribed to data bank services on nickel applications, with a promotion and advertising program to be initiated at a later date. NiDI is co-sponsoring with the Canadian Institute of Mining and Metallurgy an international symposium on nickel and its applications in August 1986 in Toronto. Through NiDI's activities, we are attracting enquiries from the nickel-consuming industries as well as from design engineers, architects, and universities. This momentum is expected to accelerate.

Since the quality of our technical service will influence to a great extent the success or failure of NiDI's activities, Technical Information Centres have been formed in North

America and Europe. In Japan, NiDI's Tokyo liaison office was officially opened in March. The purpose of these centres will be:

- to provide technical service and assistance to industry in support of nickel-containing materials generally;

- to ensure that younger engineers, designers, and managers are familiarized with nickel-containing materials generally;

- to provide a nucleus of expertise for market development projects and guidance of sponsored research;

- to provide visibility for Nickel and for the Nickel Development Institute.

For those who are interested in the legal aspects of the formation of such an industry-sponsored research and development institute such as NiDI, let me say that the Institute's objectives are clearly defined in its Charter. They provide that the Institute will defend existing applications of nickel and develop new ones; collect, analyze and disseminate technical information; and serve as a reference centre for everyone who uses or intends to use nickel and nickel-containing alloys. The Institute is, of course, prevented from any activity that would be illegal in most countries, such as, the exchange of confidential data, market sharing or price fixing.

Conclusion

The Nickel Development Institute was founded a year ago by the great majority of nickel producers in the western world, to defend traditional markets and to create new outlets for nickel, a metal that in future will keep a high profile in its several hundred thousand applications, from simple goods to high technology concepts. For a number of reasons, some nickel producers have not yet joined NiDI, but I believe I am not too optimistic when I say that in maybe two years down the road our membership may represent more than 90 percent of the western-world nickel production.

On the basis of the strategic plan submitted and endorsed by its members and the NiDI Board of Directors, the Institute was given an initial budget of $2.1 million for the first full year of operation, shouldered by the members on

the basis of a funding formula taking into account average production over the past three-year period. In the longer term, and of course provided that the work of the Institute shows results, expenditures on the order of one cent per pound of nickel sold are considered necessary to operate an effective and aggressive market promotion program.

The Nickel Development Institute is today an established organization with appropriate administration and infrastructure, an expanding team of experienced consultants, its own journal circulated worldwide, and many interesting projects in the future.

I personally believe in the future potential and the opportunities for nickel. There is no question however, that we face great threats from a host of so-called modern materials that are out there to take away what generations of development engineers have built up. Only if we tackle the problems that stand in our way will we be able to look into the future with confidence and optimism.

SCIENCE, TECHNOLOGY, AND INNOVATION IN THE MINERALS AND METALS SECTOR

Walter Curlook and C. George Miller

Introduction

The Mining Association of Canada (MAC) is the national organization of Canada's mining industry. Its 75 member companies account for the great bulk of Canada's production of metals and industrial minerals.

The mining industry has gone through five extremely difficult years. During the recession, the consumption and prices of mineral commodities collapsed. Consumption has recovered to pre-recession levels, but prices of many metals expressed in North American currencies are still very low. Mining companies have survived only because of stringent cost control and improved productivity.

The MAC estimates that, across the whole industry, the amount of product per man-year has increased by almost 50 percent since 1981. This achievement made possible the all-time record values of mineral output in 1984 and again in 1985. Employment in our industry, which was severely curtailed in 1982 and 1983, has recovered close to the 1979 level.

This productivity increase was due mainly to tighter management but also partly to the introduction of novel mining methods. We believe there is still scope for fundamental, quantum improvements due to entirely new technologic approaches.

Unfortunately, research, as well as the development of new technology, has been cut back within industry in recent years for economic reasons. Yet the imperatives of modernizing the industry, increasing productivity, and winning markets are clearer than ever. In a situation of constrained private-sector and public resources, closer coordination of the innovative efforts of industry, government and the universities is essential.

We believe that the essential principles in a new science and technology policy must be:

- involvement of industry, government and universities;
- coordination of effort among them;
- specialization among institutions;
- focus on industry's needs.

The application of these principles to the minerals and metals sector will be illustrated by reference to a specific initiative of the Mining Association.

Throughout this paper, the use of "science and technology" are intended to convey the concept of "innovation": the successful economic application of the findings of scientific research. From our viewpoint, at this time in Canada's history, the greatest need is to make effective practical use of what we know or what we can learn. All our recommendations should be read in that light.

Challenge to the Minerals and Metals Sector

In a recent speech, one of us (Curlook) reviewed some of the tasks facing this industry as it attempts to maintain or improve its cost-competitiveness with world producers. The message was that Canada must strive to be the best in the business.

Being "best" in a metals commodity business is being "lowest cost". In international commodity markets, particularly in markets that are consistently and persistently oversupplied, being the lowest-cost producer, over the long run, is our only security. In a business and economic environment where as much as 50 percent of total costs are employment costs, productivity improvement is the main route to lower costs. Productivity improvements come from changes and improvements in many areas: in methods, technology, equipment, simplification, work reorganization, job restructuring, computerization, automation. In order to make quantum improvements in productivity and achieve significant reductions in costs, we must concentrate on all of these areas at the same time. In order to stay the lowest-cost producers, we must effect productivity improvements on a continual ongoing basis.

Continuing improvements depend critically on the implementation of new technology. Canada is lagging in this respect. Our industry can and must do more. Accordingly, The Mining Association of Canada is proposing the formation of "Centres of Innovation for Mining Systems".

Consider the situation next door in the United States, where there are some interesting developments in the advancement of mining technology. The Colorado School of Mines has taken the initiative of establishing an "Engineering Research Centre in Advanced Mining Systems". The Centre will focus on automated mining systems, autonomous equipment, innovative mining methods, in-situ extraction,

computerized management information systems, and innovative fragmentation processes. Also, three new courses will be offered at the School starting in 1986: New Techniques in Mining, Mine Automation, and Mobile Robotics. This subject matter clearly describes the orientation of their thinking and of their forward-looking programs.

In a separate initiative, the Massachusetts Institute of Technology (MIT) and Pennsylvania State University (Penn State) through a joint research and education program are establishing a "Centre for Innovative Mining Systems". Initial research at this Centre will focus on ways of simplifying underground mining systems and utilizing remote control and innovative machines and methods to mine in a truly continuous and faster fashion. The founders feel that the past, slow, evolutionary pace of innovations in mines, where each small change is grafted onto existing mine systems and constrained by traditional practices, is unsuitable for accommodating the revolutionary developments in sensing and control and computerized technology that have occurred in recent years. Research is planned into robotics and artificial machine intelligence. The founders feel that one of the keys to success is that industry has to be fully involved.

Realizing that innovative research in excavation is a broad objective, exceeding the capability of any one or two institutions such as MIT or Penn State, the MIT/Penn State Centre for Innovative Mining Systems has proposed to join with other universities and with the American Society of Mechanical Engineers to form a technology group designated as the "Institute for Innovative Excavation Equipment and Systems" (the "IIEES"). We see a mammoth cooperative research and development program emerging in the USA. Universities are working closely with industry, with support expected from the National Science Foundation, in a program directed at safer and more productive excavation methods.

Contrast our approach in Canada. We are not doing enough in this area. Industry, governments, and universities are having a hard time organizing for cooperation.

There are several useful initiatives but they are not coordinated. There is, for example, a fund-raising campaign in support of two industrial chairs at Laurentian University, one in the field of Ground Control and Rock Mechanics and a second in the field of Geochemical Exploration and Remote Sensing. Moreover, the Mining Department at McGill has been looking for a candidate to fill an already-endowed chair in Mining Robotics and Automation. Queen's Mining Department is also considering taking some new initiatives. Industry supports these programs.

However, there is a concern, and indeed some evidence, that our universities are setting off on separate tangents and in a real sense are competing for increasingly scarce dollars. What seems to be required is a measure of coordination and a measure of integration in the installation of new research facilities and in the development of new programs. To get the maximum benefit for our dollars and efforts and to speed up the process will require close cooperation between Canadian universities, governments and industry.

The question is, who is in the best position to provide the necessary leadership and coordination. We believe that industry itself has the best window on the future, and we in The Mining Association of Canada are prepared to take on that leadership role.

The emphasis on university research is deliberate. Much closer identification of university research with successful innovation is clearly required in Canada. At the same time, industry must cooperate more closely with, and be prepared to support, directed work in universities and government institutions. Government laboratories and granting agencies must focus more consistently on industry priorities. They must also support appropriate applied work in universities and industry by a variety of means, including grants and contracts.

Our challenge as a nation is to put all this together.

MAC Technology Coordination Initiative

The Mining Association of Canada has begun a series of discussions within industry, as well as with both senior levels of government and universities, to promote a coordinated approach to mineral industry innovation.

A schematic representation of an institutional structure is presented in figure 1. First, there is a national board or institute named, for purposes of discussion, "The Canadian Institute of Advanced Mineral and Metal Technology" (CIAMMT). This is not a brick-and-mortar institution, but rather a committee of eminent persons meeting several times a year. Its purpose would be to establish elements of national technology strategy in support of this sector. Membership would include representatives of industry, government, and universities, together with the directors of several specialized centres (described below). National research priorities would be established.

CIAMMT would have no direct fund-granting authority. However, a granting agency such as NSERC would be

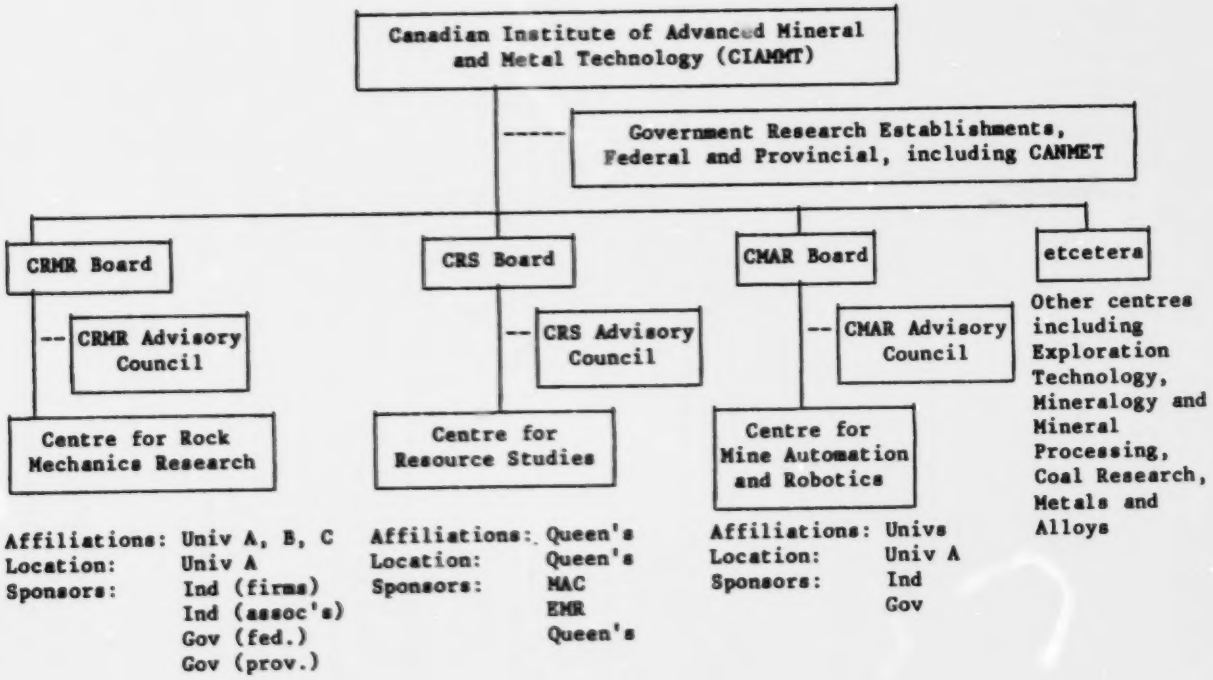

Figure 1. A Schematic Proposal for an Integrated Applied Mineral Research System

expected to exercise its authority in line with priorities and strategies established by CIAMMT. Government laboratories, as well as a series of specialized Technology Centres, would be expected to direct their efforts along the agreed lines.

The Technology Centres would all be established at a university location. Each would be affiliated with its host university for purposes of support facilities and administration. A Technology Centre would normally be affiliated with one or more additional universities for purposes of sharing facilities, accreditation for research towards advanced degrees, and so on.

It is anticipated that the main source of funds for operation will be provided on a matching basis by government and industry. "Sponsors" are defined as both of these funding agencies plus the host and affiliated universities.

Each centre would be governed by an independent Board of Directors representative of the Centre's sponsors, and responsible for operating policy and management. Each would have an Advisory Council, consisting of knowledgeable researchers, to provide program advice and coordination. Quality of director and staff will be critical to the success of each Centre.

This form of support and governance is modelled after that of the Centre for Resource Studies (CRS), a highly successful mineral policy research institute located at Queen's University and sponsored by Energy, Mines and Resources Canada, Queen's University, and The Mining Association of Canada. CRS has demonstrated that a cooperative approach among three sponsors can result in timely, high-quality work, applied to significant problems. The independence of the university is not compromised, but the research is focused on the issues facing the industry.

Each Technology Centre would be regarded as a national institution, a national centre of excellence. As such, it would carry out some work in-house, but would also support work at affiliated universities across the country. In this way it would exercise a benign leadership and coordinating influence on other institutions.

To be successful, this system will require the cooperation of agencies which are accustomed to autonomy. However, the partial surrender of autonomy can also yield enormous benefits to participating institutions:

- the possibility of increased funding, especially from industry;
- more effective, faster innovation in Canada;

- the opportunity for academics and government researchers to be associated with commercial application of their discoveries;
- much more efficient use of scarce financial and human resources.

We have another example in Canada, besides CRS, of cooperative research between several universities, the government and industry, and that is IREM-MERI, "Institut de Recerche en Exploration Minerale - Mineral Exploration Research Institute". It was established in 1972 with a mandate to serve as a national centre of excellence in the field of mineral exploration research. It combines the resources of the geology and geological engineering departments of École Polytechnique, McGill University and Université de Montréal, and serves as the facility through which these departments interface with government and industry. Representatives from the three universities, from the provincial and federal governments, and industries working in Quebec, sit on the Institute's Board of Directors. The work of the Institute could be enhanced, in our opinion, by greater participation by industry. Also, the question arises as to whether its scope can be expanded beyond the province of Quebec. For this to happen, it will require the affiliation of other Canadian universities and industry from outside of Quebec. This Institute rightfully falls under the proposed caption "Centre(s) for Geochemical and Geophysical Exploration Technology".

Another question, yet to be answered, is whether in certain disciplines there should be more than one Centre.

The MAC believes that Canada's situation calls for a cooperative approach to technology development and implementation. We are confident that battles over "turf" will be infrequent, brief, and minor. The intrinsic benefits speak for themselves. Initial discussions with the potential actors indicate that cooperation will be forthcoming, in the broader interest of Canada.

THE ROLE OF EXTERNAL INSTITUTIONS IN NEW TECHNOLOGY: THE UNIVERSITIES

Michael Sayer

In Canada, a large fraction of the available scientific manpower resides within the university community. Any discussion of the role of external institutions in technological innovation in the mineral industry must therefore consider what the universities can and have to offer. In this paper I would like to consider this question generally at first, and then to outline some specific initiatives in the materials area that we have taken at Queen's in the last two years. Successful innovation requires several ingredients:

- recognition of a problem (or opportunity);
- a basis of knowledge to provide a solution;
- the motivation to develop a prototype product or process;
- the financial and technical resources for commercial implementation.

In the past, the preoccupation of the universities has been with the development of knowledge, with some interest in problems, often sparked within an international rather than a Canadian context. Canadian problems and opportunities, as well as prototype and commercial development, have been the concern of industry, often on the basis of past practice. Over the past few years the evidence is strong that this division of assumed responsibilities and interests is changing, and changing at a time when financial incentives - the matching of industrial funds, NSERC Industrial Chairs, bridging appointments etc. - provide a powerful incentive for universities to work in closer collaboration with industry. In addition, the increasing availability of faculty positions provides some opportunity for research programs to change course. The potential for change and for industry input into this process is very significant.

To a long-time university faculty member, it is very clear that university staff currently have a much increased interest in the application of their research. This goes far beyond perceived changes in priorities in government funding, and is more likely due to the interests of a maturing faculty in new challenges in non-traditional areas. For

example, in 1970, a group at Queen's discussed the establishment of a Centre for Metal and Mineral Technology. Five people began the discussions, five people ended them (unsuccessfully). The general worry at that time was how such activities would fit in with the time available for basic peer-adjudicated research. Other institutions did set up Materials Research Centres, a number of which have done excellent basic research, but the record of their interaction with industry has generally not been impressive. In contrast, in 1984, an Advanced Materials Technology Unit was proposed at Queen's with a major objective being to act as a liaison body between the university and industry. Forty people appeared at the first meeting, and interest has remained high even though the industrial activities have begun to require commitment of time and effort.

On the industrial side, as complex technology becomes more widespread, efforts to improve the knowledge base are apparent through collaborative organizations, either industry-based or involving industry-university links. These appear to be useful for direct innovation and development, and have a role as an information gateway to guide internal company decision-making in new technical areas. The perceived value of such organizations to industry is clear from the entry fees that many Canadian companies are willing to pay to technical workshops at U.S. institutions such as MIT, and from the existence of industrial collectives such as MIROC, NiDI and HDRK. A university-industry council is now being formed in the ceramic industry, and similar activities are in progress in polymers and process development. A new feature of these organizations is the willingness of different universities to cooperate to provide specific areas of expertise to the overall enterprise, rather than insisting on an exclusive mandate for one university.

The question is therefore not how collaboration can be triggered, but how can these changes in attitudes to joint university-industry collaboration be mobilized and linked most effectively to give rise to commercially successful innovation and development. The latter should provide long-term benefits to both the university and the industry. How do we bring the people with Canadian problems into contact with those who can assist with a solution; or alternatively, how do we link Canadian academic expertise with those who require its results.

Past practice has shown that we do not do it through formal conferences, government task forces, and official organizations. The vital interaction results from personal contacts between individuals who wish to collaborate for mutual benefit. The role of organizations and structures

within which they operate and work is to facilitate this personal activity.

The following factors are pertinent to innovation resulting from interaction between university staff and industrial partners:

- identification of areas of mutual interest;
- development and growth of the necessary expertise;
- understanding of the imperatives of all participants;
- personal contacts and effective collaboration.

All of these topics, except possibly the last, have been the subject of endless debate, usually in a negative sense: ...."nobody is interested in my work in Canada" ...."we have to go to the United States for useful advice"...."All that university professors want to do is to publish"...."The company wants my expertise free and if NSERC finds out it will cut my grant"....!

We have taken two initiatives at Queen's recently which address these factors in a creative way. The first is the Advanced Materials Technology Unit, in the Faculty of Applied Science;[1] the second is the Enterprise/Innovation Centre. The AMTU is a university/industry liaison organization involving faculty members in engineering, the sciences and business with member companies in polymers, metals, ceramics, electronics and various other industries. Its primary objective is to act as a linking organization designed to build up personal contacts and to facilitate collaboration between a wide range of academic staff and industrial organizations. Its operating procedures have been guided by earlier successful interactions with industry. Direct contract activity is regarded as an important secondary objective rather than the primary function of the organization.

The AMTU offers the following major features.

1. Regularly scheduled workshops in areas of pressing concern to both the university and the industrial members. Workshops to date have taken place on Advanced Ceramics, Non-Destructive Testing, and Materials Degradation in Aggressive Environments. The next meeting will be held in October on Composite Materials.

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1. See appendix A at end of this paper for a description of areas of interest of the AMTU.

2. Appointment of faculty members as liaison officers to participating companies. These officers spend two to four days per year with the company - not as a consultant, but to understand the nature of the problems which arise in the industry. They act as a "window" for the company into both Queen's and the academic community in general. They establish personal contacts and, it is to be hoped, build up a mutual understanding of each sides' requirements.

3. Utilization of university facilities and expertise.

4. A specialized program of graduate studies and short courses.

5. Organization of research seminars, shared equipment, contracts and technical support.

In the first year of operation, 13 companies have joined AMTU and 4 workshops have been held. A number of specialized contracts have been let and over 100 people from industry and government have been brought to the campus. The liaison officer program is under way, with reasonable success.

We have learned from organizing the workshops that the format cannot always be directly appropriate to a university environment. A conference which looks excellent to academics - good speakers, all of whom are expert in their field - will often be too academic to suit the interest of the industrial participants. On the other hand, speakers who appeal to the industrial people often also work well with the university staff. Our response to this fact has been to ensure that conference planning always involves both industrial affiliates and university staff.

While university-industry relations have been improved, an unexpected result has been the effectiveness of industry-industry interactions. Large companies have been made aware of dynamic small companies, and commercial relationships have been established. In one case, a major commercial endeavour has been launched from interactions between an affilitate company, AMTU, and an non-affiliate conference participant.

The second initiative at Queen's is more closely allied to innovation. Innovation does take place spontaneously in the university and in its associated institutions. We have recently established the Canadian Enterprise/Innovation Centre under its Director, Dr. Calvin Cupp, to aggressively market technology the university has developed.

This activity can provide technical and financial feedback to the university on the technology developed by its faculty, and provide economic benefits to companies to which the technology is transferred.

Neither of these initiatives will, of themselves, ensure innovation in mineral processing or any other area. However, they facilitate the interaction and growth of the people and departments that do innovate. The business of the university is teaching, but it is teaching by professionals; in engineering and science, professionalism is innovation and design.

The university has a basic commitment to long-term teaching and research of high quality. However, basic research in areas of current Canadian industrial research is still good research, and such studies are the basis of innovation. The best form of guidance from the industry is by on-going collaboration with a university researcher or department. Such projects need not be long term or expensive, and the use of matching funding can reduce costs even further. On-going projects can play a vital role in preparing the ground for major initiatives which may then have significant economic impact for the participating company.

As an observer from outside the mining industry, I believe that one of the major reasons for the past lack of interaction between the industry and universities is the size of the industrial units. In good times, large companies with big research staffs and well defined products do not need outside assistance. However in times of change, new expertise has to be consulted and developed - for process technology, new products and diversification. If any deficiencies in technical capabilities currently exist, the responsibility must at least be shared by both the university and the industrial sectors. It is surely in our mutual interest to devise on-going methods of collaboration to minimize such deficiences in the future.

Appendix A Advanced Materials Technology Unit - Areas of Interest

Materials and Materials Processing

- alloys, metals, magnetic materials
- ion beam modification of materials
- space processing
- ceramic characterization
- piezoelectrics
- thin films and interface studies
- polymer engineering

Analytical Techniques

- accelerator based analysis
- Nuclear magnetic resonance
- Chemical, EDAX, SEM

Non-Destructive Testing

- Ultrasonics
- magnetic methods - pipeline inspection
- laser induced NDE
- industrial instrumentation and control

Corrosion

- electrochemistry
- protective coatings

Plus substantial involvement with:

- a range of small and large companies and government agencies;
- Queen's School of Business, with interests in marketing and innovation;
- Queen's Technology Transfer Office/Patents and Licensing.

THE ROLE OF EXTERNAL INSTITUTIONS IN NEW TECHNOLOGY: CONSULTING FIRMS

Gerry G. Hatch

Background

This presentation is concerned with the role of consulting engineers in developing and applying new technology, and in technology transfer from other fields and mining industries in other countries. Some general comments will be made on the activities of Canadian consulting engineering organizations in the mining and metallurgical fields. However, most of my remarks will relate to my own experience and perspectives.

Thirty years ago Canadian engineering firms were quite strong in civil engineering but were weak with regard to process development and project management skills. In the mining and metallurgical fields there were competent Canadian geological consulting organizations and mineral dressing design engineering firms. The process metallurgical and project management fields, beyond the ore milling stage, were populated by Canadian subsidiaries of large American organizations.

In our firm's case we undertook to develop an organization with strong process engineering skills, complemented with a multi-discipline design engineering staff and project, construction management personnel. To us, process engineering means being knowledgeable in all the disciplines involved in a process. We believe that having metallurgical engineers with practical experience in specific processes is important but not sufficient. As a result we also hired young engineers with graduate training in chemical, civil, mechanical, electrical, environmental and electronic engineering. With due respect to the metallurgical and/or chemical engineering aspects of a process, each process depends on developing efficient equipment design and control systems. This, in turn, means that specialists in fluid mechanics, heat transfer, stress analysis, materials engineering, instrumentation and process control are essential. These multi-discipline skills together with practical experience are particularly important in developing new commercial processes.

Our firm took the position that where we worked with client research and development staffs, as well as operating

and engineering personnel, we could help our clients bridge the gap between the laboratory, pilot and commercial stages of process development. Examples of successful new process systems include Falconbridge's process plant for producing ferro-nickel from laterite ores, Noranda's continuous reactor process for smelting copper concentrates, custom engineering of electric steelmaking and continuous caster systems, and the development of QIT's sophisticated smelting plants in Quebec and South Africa. These operations were successful for the following two basic reasons:

1. Top management of our clients set a positive climate for the development of the projects.[1]

2. Between our own and our clients' organizations, innovative and analytical multidiscipline process engineers and design engineering teams, complemented by professional project and construction management personnel, were applied on each project.

Point 1 cannot be over-emphasized: without the full support of senior management, these projects would not have been nearly as successful.

The examples referred to were carried out in the 1960s and 70s. At that time capital and financing costs had increased to such an extent that these managements appreciated that, without innovative and detailed homework, both the total project cost and operability would be jeopardized. As you will recall, in those years, the prices for metals were better than they are today. This situation undoubtedly allowed management to pursue projects more aggressively than at present.

Period of Downturn to the Present Time

We all know the dramatic reduction of commodity metal prices that took place in the past few years; the situation is still with us. In this period our major clients reduced their overheads drastically; now they find that they must reduce costs further still, and improve their product quality. Both these thrusts require increased emphasis on tech-

1. See G.G. Hatch, T.M. Noskiewicz and J.D. Good, "Top Management and Capital Spending Projects", Metallurgical Society of AIME, paper No. A74-90, reprinted 1984.

nology. However, most of our clients no longer have the cash flow for major technical developments. In any case, with the exception of new gold operations, the consultants' role in recent years, and currently, has been to innovate and work with the client to develop equipment systems yielding higher quality products and higher productivity. Our firm might not have survived the downturn if we did not have our multidiscipline innovative and analytical skills to draw upon.

The Future

In recent years Japan's success in expanding its basic and manufacturing industries has been well documented. When one examines the Japanese situation, one sees that the top management of industry is market driven, but, more importantly, technologically driven. Simply wanting to be technologically driven is not good enough. The answer is that the Japanese government and financial institutions have provided the funds in terms of tax benefits, low interest rates, fast write-offs, so that selected industries were able to develop the funds required to do the technological homework.

Reference has been made to specific new developments which top management of Canadian clients supported in the 1960s and 70s. These efforts are not enough: it is essential that government provide additional incentives, and that senior levels of management be technologically driven. Our politicians do support basic research. However, repeatedly over the years, the writer has found that **the real technological gains result from having the applied, innovative and technical skills, funds, and determination to develop the research results and/or licensed systems into successful operating units.**

I understand that the Department of Revenue has a committee to re-define what is research and what is not research for tax purposes. Frankly, I believe that all technological work, research, process development and engineering, up to the point of letting equipment orders for fabrication and construction contracts, should be treated at the same tax rate. Under these conditions it is estimated that last year, excluding the oil and gas industry, the tax revenue would be reduced by less than $200 million to do the required test and technical work for all the manufacturing projects built in 1985. Industry needs general ground rules that will allow them to function like the Japanese, to do the technical work and then finance each project on its own merits.

As far as the consulting fraternity is concerned, engineering firms will have to do a better job of selling the difference between multi-disciplinary and innovative problem-solving skills and straight design engineering. Too many of firms fit the description offered by Tom Peters in his "Passion for Excellence" seminar: "Selling on price is the simplest, laziest, dumbest, easiest thing to do ... which is why 8 out of 10 do it".

In our own search for excellence, our firm is developing and acquiring software for analyzing process systems, and is expanding our thrust in the fields of process computer control as well as CAD. Project and construction management, combined with competent start-up teams, will be more essential than ever if projects are to realize their anticipated payouts.

Some major engineering organizations, including our own, are restructuring themselves so that they can invest directly in operating businesses and enter activities such as research and development, both of which traditionally have been outside the domain of consulting engineering. The objectives of such action include:

- leveling the cyclic swings inherent in capital spending projects;
- better utilization of skills;
- first hand knowledge of the attitudes of the producer and seller of goods.

Finally, a few words on technology transfer. Successful technology transfer will be more important than ever. With equipment and control systems becoming more and more sophisticated, the need for analytical and innovative multi-disciplinary skills will be more important than ever. There are innumerable cases where owners have experienced disasters, small and large, by assuming that purchased technology can be successfully introduced without the technical homework being properly done in each specific case.

Conclusion

The role of new technology has become dominant in projects in the 1980s. More than ever, this will require integrating the skills of external institutions with the needs of producers. Consulting engineering firms with multi-disciplinary talents have better survived the recent downturn than those geared to straight design engineering. The success-

ful application of their skills to current needs requires a recognition by all levels of clients' management that engineering the new technology is really the final step in R&D. It is more important than ever to effectively blend the unique strengths of each of the groups involved in this process: research, operations, management, and engineering.

THE ROLE OF EXTERNAL INSTITUTIONS IN NEW TECHNOLOGY: MINING EQUIPMENT MANUFACTURERS

Duncan Hutchison

Perhaps before I present my views on the approach which the mining equipment industry should play toward the introduction of new technology within the mineral sector, it would be in order for me to say a few words about Continuous Mining Systems Ltd., for those who may not be familiar with it. Our company designs, manufacturers and markets specialized and technically advanced equipment for the mining industry. It was formed in 1984, with funding support from Inco Ltd. and with further repayable loans to be provided from both the federal and provincial governments. Inco's initiative got the company up and running, and we are pleased to report that the first year and a half of operation has been successful in establishing ourselves as a viable business. During this time we have also introduced our products to such companies as Brunswick Mining & Smelting, Dome Mines, Falconbridge, Inco Manitoba Division, Inco Sudbury Division, Pamour and Sherritt Gordon Mines.

Let us return to the topic at hand. There are in essence four basic approaches which can be taken by an equipment supplier toward providing the end user with technologically advanced equipment.

The first is to provide equipment which has been improved over similar units currently in use, and to market this product on the basis of specific advantages such as reduced maintenance, improved running costs, better productivity and so on, all of which are desirable features for the mining sector. The introduction of LHDs with totally enclosed brake systems, modulated transmissions, centralized lubrication, etc. is just one example of this type of approach.

A second approach is to modify the way in which existing equipment is utilized within the mine environment to improve ore extraction, improve safety, and reduce mine development costs. The use of radio remote control equipment has addressed this area, and has provided significant strides toward reducing mining costs in particular situations, while at the same time enhancing safety for mine operators.

A third avenue is to introduce new product technology that can be incorporated within established mining configurations. Electric hydraulic drilling, water jet drilling, hydraulic impactors, electrically powered LHDs, and, more recently, electric trucks are examples of this approach.

The fourth approach, and the direction which has been taken within Continuous Mining Systems Limited, is to develop a system approach in cooperation with the mining industry, an approach that lets us introduce technologically advanced equipment in an organization that includes a built-in method for applying this equipment to a mining situation. The result is equipment that can dramatically improve productivity, reduce unit costs, and at the same time ensure that a high regard for worker safety is maintained.

A continuous hardrock mining system utilizing equipment designed and developed in conjunction with mining operations personnel has been and will continue to be our main goal. The mining system being developed will allow, in appropriate orebodies, the concentration of mining activity in fewer but larger areas, thereby reducing the development required to produce a certain volume of ore. Vertical retreat mining, utilizing large diameter blastholes drilled with equipment developed by drillers for accuracy of hole alignment, ease of maintenance, and eventual automation has been the first stage of development.

The second phase of innovation in the mining system, the incorporation of new developments in blasting technology in order to produce ore breakage that is suitably sized for mechanized extraction, is presently going on within the mining operations.

The third step has been to develop a continuous in-line loading unit, with the ability to handle run-of-mine material at extraction rates up to 10 times the productivity offered by conventional loading systems.

A fourth component of the mining system is a low-profile crusher which can be transported to the production area to provide material sizing adjacent to the mining operation, thereby producing material which is reduced in size to facilitate subsequent handling by conveyor.

Finally, a conveying system which will include the ability to negotiate corners through use of an innovative belt-bender storage system forms still another component of the mining system. This will permit continuous transfer of material from the crusher to the ore pass without the need for transfer conveyors, etc.

Our approach to introducing a mining system with technologically advanced components involves both in-house

equipment development and the development of system components with outside supplies. Consideration is being given in all cases to the possibility for eventual automation of the new equipment and methods.

Adopting the system approach to technological advancement in the mining industry is in my view the optimum direction to be taken by equipment suppliers, since the advantages of each component complements the next, to produce efficiencies and cost reductions throughout the operation.

THE ROLE OF OUTOKUMPU IN NEW TECHNOLOGY, AS A MINING COMPANY AND AS AN EQUIPMENT MANUFACTURER

Adrian Molinari

Introduction

Outokumpu Oy is Finland's largest mining and metallurgical company, with an annual turnover of approximately $1 billion, and 9,000 employees. The company is highly integrated, with activities which include exploration, mining, mineral processing, metal refining, metal fabricating, equipment manufacture and marketing of technology. In Outokumpu's basic production, copper and stainless steel are the two most important products. Other major metals are zinc, nickel, cobalt, precious metals and ferro-chrome.

Outokumpu is also an internationally known supplier of processes, machines and equipment for the mining and metallurgical industry. The technology and equipment which it has developed are largely the result of its own intensive research and development. The importance the company attaches to R&D is shown by its policy of investing about 4 percent of turnover in this activity. Outokumpu's research and development facilities include:

- Metallurgical Research Centre
- Electronics and Physics Research Centre
- Mining Technology Group

Limitations and Challenges

As a mining company located in Finland, Outokumpu faces some formidable constraints in maintaining growth. The most obvious are:

- modest mineral resources, with small orebodies that are blind or hidden under glacial deposits, low-grade complex polymetallic ores, and costly underground mining;

- requirements to protect the unspoiled environment, where mines may produce but not pollute;

- the high cost of energy and labour;

- a small domestic market for raw materials and manufactured goods, with export markets far away from the producing plants.

The above constraints are being minimized by specific policies, which include:

- intensive research and development efforts to find innovative and highly feasible solutions to maximize exploitation of limited mineral resources efficiently;

- emphasis on international activities, and export of the company's metal products;

- continued funding of R&D activities, by selling Outokumpu's technology and machines to mining companies throughout the world.

At Outokumpu Adaptation of New Technology Requires Close Interaction between Various Institutions

Outokumpu has long realized that its survival among world giants of mining is directly dependent on efficient technology, which in turn is based on extensive research and development work. This work should not be limited to chemical and metallurgical research alone, but must also embrace the machinery and instruments needed in today's modern plants. A new and innovative process developed in any laboratory through extensive R&D efforts is of no economic benefit if there is no plant-scale process machinery to support it.

Within the Outokumpu group, there is a close interaction between the various research groups, mine operators, and equipment manufacturers to ensure that the machines developed are practically designed to fulfill the operators' requirements for high productivity equipment. This vital interaction, especially between the equipment manufacturer and the mine operators, is an on-going procedure, which extends far beyond the design and start-up stage. This kind of continuing relationship is vital, not only for specific product development but also to find new applications for techniques or equipment already developed (for example, tramp metal detector for security applications, on-stream analyzer technique for ore sorting).

Outokumpu maintains very close contact with the Finnish technical universities for the purpose of influencing and advising on research programs, and ensuring that new

graduates receive training in the areas of new technology implemented by the company. Company employees also lecture regularly at the universities.

How Do We Perceive Our Company's Role in Introducing New Technology to the Canadian Mining Industry

As a subsidiary of Outokumpu Oy, a mining company first and equipment supplier second, our company is in a rather unique and fortunate position of being able to introduce new processes and equipment which has been tested and proven in the plants of Outokumpu. The technology and equipment developed in our own plants must meet certain basic criteria before it is introduced to the mining industry in Canada: it must, of course, produce economic benefits to the user; the technology and equipment must have synergy with the processes and operating methods commonly used in Canada; the sale of technology and equipment must be also profitable to our own company.

The role of Outokumpu Equipment Canada Ltd. in bringing in new technology can be summarized as follows:

- create an awareness within the Canadian mining industry of the new developments in use within our own plants in Finland;
- relate operating experiences and economic benefits from the installations in other plants, in Finland and elsewhere;
- re-engineer or modify the equipment to meet local conditions and practices;
- provide the technical know-how to ensure that the technology is used correctly and efficiently;
- ensure that the new technology produces the desired results, through <u>continuing</u> service and operator training.

DIGEST OF DISCUSSIONS

Margot Wojciechowski

Introduction

The Canadian mining industry is heavily dependent on technological innovation, to stay competitive in the face of rising third world production and slow growth in demand. The rate of both innovation and technology transfer is increasing rapidly, participants pointed out, and the industry will have to work much harder at innovation than it is doing at present in order to catch up and maintain a strong competitive position. Technology should not be considered simply a means to improving productivity, it was suggested, but rather as a driving force for survival within the industry.

The hoped-for economic upturn cannot be counted upon to restore economic strength to the industry. Nor can emerging third world markets be expected to restore vigor to market demand, participants warned, because, first, third world countries themselves are increasingly becoming strong and low-cost competitors, and second, because studies have indicated that third world countries are in many cases "leapfrogging" technologies of consumption, moving directly into fibre optics and plastic buckets, for example, and bypassing the stage of heavy consumption of metals that has characterized industrializing nations in past years.

The Canadian mining industry can no longer survive just by selling primary mineral products. It must diversify into downstream and upstream technologies and products, including exploration, mining, and processing methods and equipment, as well as new applications and high-value-added mineral products. It must market all these goods and services, in Canada and abroad. It must utilize technology to achieve greater flexibility in production, in order to become more responsive and less vulnerable to fluctuations in market demand.

Participants identified two fundamental requirements within companies to permit the introduction of innovations:

- management support for innovation;
- people in the organization with the required skills to put the innovation into practice, either through internal R&D or through technology transfer.

In other words, companies must have technically advanced people in both R&D and operations, and CEOs that are commited to new approaches and to providing the necessary funding.

It was noted that R&D is not, contrary to popular belief, fuelled by the availability of cash; it is fuelled by need, generally at a time when cash is least available. Therefore, obtaining funding for R&D activities is a perennial problem, one that often requires a strong effort on the part of R&D performers to convince senior management and operating staff of the payback, the potential benefits, from R&D activities. This flow of information and dollars must be a two-way street, one that facilitates the application of R&D results to operations by ensuring close communication with the end-users, where the payoffs will ultimately be realized.

Unfortunately, participants agreed, the R&D and innovation efforts in the mineral sector in Canada suffer from a number of weaknesses, most prominent of which are the low level of overall funding, the fragmentation and isolation of individual efforts, the lack of focus on areas of greatest need and potential for reward, and the funding cuts during periods of low profitability. There was a strong sense of agreement that there is a need to coordinate and focus mineral-related R&D, innovation activities, and funding in Canada. Such a move, it was argued, could improve the effectiveness of the existing level of R&D and innovation activities, increase the awareness of the need for technological innovation among industry management, improve communication among the broad range of organizations that can contribute to and benefit from innovation, and last but not least, lead to an increase in overall R&D and innovation funding and activities.

Problems and Needs

Level of Funding

Participants noted that the level of mineral-related R&D funding in Canada is low, compared to other competitor nations such as Australia, Sweden, and South Africa. With a few exceptions, most notably Alcan and Inco, Canadian mining companies are spending relatively little on R&D and innovation, well below one percent of revenues. Some participants noted that increases in industry funding for R&D are unlikely at the present time, due to the economic difficulties faced by many companies. Others argued that this is pre-

cisely why the companies must put more effort into R&D, that innovation is in fact fuelled by a driving need to survive that overcomes the lack of cash. It was also noted that several Canadian mining firms were able to come up with very large sums for capital expenditures and acquisitions in the past year, but were unable to afford even $1 million for R&D.

Government expenditures were felt to be low as well. Federal R&D expenditures on metals, measured as a percent of sales, were lowest of all the resource sectors. This situation will become even worse if the Neilsen Task Force public recommendation of a 25-percent cut in CANMET funding becomes government policy. Participants also expressed concern that the proposal to move EMR's research grant program for mineral-related R&D to NSERC would be an additional problem to the mineral sector, since at present NSERC has little expertise in evaluation of mineral-related proposals.

Canadian funding of R&D does not compare well with the effort of the Finnish firm, Outokumpu, which, as Adrian Molinari reported, spends between 2 and 4 percent of its annual turnover of about $1 billion on R&D and innovation, about $20 to 40 million per year. Canadian mining companies, by comparison, produced minerals worth about $13 billion in 1983, and together spent $41 million on R&D, about the same as Outokumpu. Canadian R&D expenditures for nonferrous smelting and refining activities were higher than for mining (1.3 vs. 0.6, as percent of sales) but still well behind Outokumpu's 2 to 4 percent. Outokumpu's funding goes to support basic and applied R&D in house and in universities, as well as process and equipment development. In his presentation, Molinari pointed out that Outokumpu, although government owned, is not subsidized, and that it must raise needed capital in the financial markets.

Fragmentation and Isolation

Participants were concerned that R&D is carried out in scattered locations, with too little communication between organizations and even within them. As a result, there is duplication of effort, inefficient effort in small organizations that lack a critical mass of researchers or the scale of equipment needed, gaps in areas in need of attention, lack of application of R&D results, and other inefficiencies.

Within companies, there is a need for multidisciplinary skills to achieve technological breakthroughs and apply them to operations. Most companies lack the broad base of skills

needed at the operating level to bring in and adapt peripheral technologies in areas such as electronics, robotics, and computing. Gerry Hatch advised that consulting firms can be very useful here, helping to bridge knowledge gaps between sources of technology and end users. It was suggested by other participants that increased employment opportunities for summer students and recent graduates can help, by exposing the students to operations and associated problems, and by bringing new ideas and approaches into the operations.

Another source of help in bringing in new technologies suggested by Roy Woodbridge is forward integration into firms in peripheral technologies. He and others cited the automotive industry as an example of the effective use of forward integration into companies that provide new technical capabilities, as well as companies that have the potential to contribute to innovation. It was noted that Noranda has made some moves to forward integration, but more as corporate investments than as sources of information and new technologies. Inco has succeeded in alloys, if not in batteries.

Product R&D was cited as an area in which it may be particularly difficult to overcome the problems of fragmentation. Although there has been considerable activity in setting up organizations and joint ventures for marketing and product R&D such as the Nickel Development Institute (NiDI) which was described in Hans Schade's presentation, the focus has generally been on the commodities being produced, such as steel, asbestos, nickel, or brass, for example, rather than on the particular material needs of the various markets.

In mining R&D, Continuous Mining Systems (CMS) and Hardrock Mining Research Ltd. (Hdrk) were cited as examples of cooperation that are moves in the right direction, but there was some concern that they might lack the scale of effort needed for significant breakthroughs. It was suggested repeatedly that there is a real need for a cooperative effort by the entire private sector, backed by the federal and provincial governments and taking advantage of every available resource in Canada. It should focus on the industry's problems, draw on the industry's presently scattered expertise and overcome the present isolation of efforts. Government facilities and some university research programs should be closely involved, and also focused on problem solving for the industry.

It was noted that Outokumpu had at one stage tried to decentralize its R&D and innovation activities, but had found by trial and error that a centralized effort, supported by closely connected university R&D programs, is

the most effective. Centralization has improved communication and provided the needed critical mass in a number of areas of expertise. Falconbridge also found advantages in improved communication when it re-integrated its R&D into operations, according to Frank Pickard's presentation.

Participants questioned whether the need for centralization and large-scale cooperative research efforts means in effect that small mines will not have access to R&D and innovation, and consequently may cease to be competitive. The response from several sources was that this would not be the case. For one thing, a number of smaller mines are already affiliated with larger companies which can assist in technology transfer. For another, through R&D joint ventures, small firms would be able to participate in large projects to the extent of their capabilities. Furthermore, the cooperative approach recommended by seminar participants should result in the free flow of innovative ideas and new equipment and process developments to all firms, whether or not they are directly involved in the R&D. The major handicap facing small firms, (and many large ones as well, participants suggested) will be the lack of in-house expertise to identify technology needs and to facilitate innovation, rather than a lack of information or opportunity.

Neglected Areas

While there was no complete consensus on any one single area of neglect in mineral R&D and technological innovation, there was considerable support for the view that the following areas need more attention:

- mining R&D;
- new products and marketing;
- demonstration and commercialization of available technologies;
- mining equipment development and manufacturing;
- basic R&D and long-term applied R&D, in support of the above shorter-term activities.

1. Mining R&D

There was general agreement that mining per se is particularly neglected in terms of R&D funding and activities. Industry R&D in mining (as opposed to process metallurgy) is limited and, with a few notable exceptions, aimed only at in-house incremental improvements to existing operations.

The federal in-house activities, centering on CANMET, also place little emphasis on mining per se. Federal support through grants to industry and university are low for mining as well. The existing EMR Research Agreements program, with funding totalling under $1 million for earth sciences and minerals, may be transfered to NSERC, it was reported. NSERC, however, has no mining committee at present and allocated only 3 percent of its operating grants, about $2 million, to mining-related R&D in 1984/85.

This relative neglect of mining R&D was felt by many to be particularly serious, because of their view that, in the mineral sector, mining offers the greatest potential for major technological advances that will improve productivity and reduce the cost of the final products.

2. New Products and Marketing

A number of participants pointed out that the end-use aspects of R&D are crucial as well, and as neglected, if not more so, as mining R&D. It was stressed the Canadian industry must be the lowest-cost producer, not just of commodities, but of commodities that can be sold.

With the exception of Alcan (which spent over $40 million on product R&D in 1985) very few Canadian companies do any product development R&D. For nickel, Inco used to do all the product research, with a budget of about $20 million per year in the 1970s. Now, work in this area has been taken over by the Nickel Development Institute (NiDI), with 14 member companies and a budget of about $2 million last year. Most of NiDI's activities are related to market development rather than new product development, since there are a great many product innovations on the shelf and available, but not yet commercialized. Some work is under way on the addition of nickel salts and fibres to plastics.

For metals in general, almost no product development work is being done in Canada at present. It was suggested that universities might play a role in this sort of R&D, with the warning added that, even in universities, applied studies of this sort should always keep end-use needs in mind.

Participants asked about lessons that have been learned from past experience with commodity-based R&D and marketing groups that might be applied to

future cooperative R&D efforts. Among the suggestions offered were:

- don't expend a lot of effort on statistical studies and data bases;
- don't build up a large organization or infrastructure - instead, use consultants and contract out;
- don't use the organization to sell products or technology directly to consumers - use it to enlarge the market as a whole through education and public relations, and to service the producers and sellers;
- don't separate R&D from marketing - keep the customers' needs and new opportunities in view;
- once a commodity's markets are attacked by substitutes, don't concentrate too much effort on defending these markets - they are probably a lost cause, in most cases;
- focus instead on new markets, either through new applications of existing products, or development of new products to meet specific needs.

Product R&D and marketing organizations tend to be commodity-oriented, such as for nickel, steel, asbestos, brass, lead/zinc, etc. One multi-material exception that was discussed is the Advanced Materials Technology Unit at Queen's University, but it was noted that, while this group does have some members with an interest in metallic materials, the group as a whole has no particular interest in seeing that the materials being studied are or contain metals.

In response to the question of whether all commodities need cooperative marketing ventures, several participants argued that the best marketing approach is a direct link between the producer and the customer, focusing on specific needs and markets. Where marketing organizations are useful, they should be international rather than exclusively Canadian, in both membership and focus of activities.

3. Demonstration and Commercialization

Participants agreed that too little effort is made to ensure that innovations resulting from successful R&D are actually put into use and diffused through the industry. The essential ingredients for realizing the benefits of R&D were identified as:

- definition of need by the end user;
- communication, linking every step of the process from innovation to application;
- a "champion", with the support of top management, who follows and pushes the process to its conclusion;
- adequate funding for the demonstration and commercialization phases;
- if required, an aggressive marketing effort to sell the resulting process or product as widely as possible.

Without any one of these factors, a potentially useful innovation may well stay on the shelf, wasting the resources that went to its early stages of development. Human skills and enthusiasm were identified as a key ingredient. R&D people, it was noted, rarely feel any responsibility for implementing the results of their work. This is especially true in university, government and even industry laboratories that have no direct links between researchers and the operations where the R&D is to be applied. This situation can be turned around, particularly through increased communication with end users beginning with the initiation of R&D projects and following through the innovation process step by step. There should be industry involvement of some sort from the earliest stages, and some concept of payback to drive progress to the application and commercialization stages. This will have the additional benefit, it was suggested, of motivating researchers by showing positive results arising from their work.

4. Mining and Process Equipment Industry

Canada's poor showing in this area was attributed to a number of factors, including:

- neglect of the commercialization aspects of innovation, as noted above;
- explicit decisions by mining companies to stay out of the direct business of manufacturing equipment;
  an explicit decision by CANMET to stay out of the equipment development business;
- barriers to starting up new Canadian equipment companies, in the face of shrinking markets, conservative buying habits of mining management,

and strong multinationals with associated servicing facilities now dominating the Canadian mining equipment market;
- high technology firms presently operating in Canada are looking mainly at export markets, and have not targeted Canadian mining as a significant potential market for their products.

However, some participants stressed that Canadian mining firms cannot continue to rely on imported technology, because this will mean that they will always be at least one step behind the leaders. In order to achieve the maximum potential benefits, it was suggested, mining companies should integrate forward into Canadian or other high tech companies, to ensure two-way communication and attention to industry-related needs. Alcan is pursuing this course with Spar Aerospace, and Inco is moving in this direction with CMS.

Canadian mining equipment companies, participants were warned, must avoid the error of overdesigning equipment to the point that the purchasers' employees may lack the necessary skills to operate it and maintain it. Successful manufacturers must design with technical needs in mind, but also with the operators' skill levels in mind. Outokumpu, for example, makes a point of designing its equipment and processes so they can be operated by the operators, and do not require additional technical staff in operations or in maintenance.

The case of Continuous Mining Systems (CMS) was cited as an example of the benefits of close collaboration between manufacturers and users. Inco now develops equipment prototypes in-house, debugs them in its research mine, and turns them over to CMS, its recently-established subsidiary, for manufacturing. CMS produces the equipment for Inco and markets it to other mining companies, and can make adaptations, drawing again on Inco in-house expertise as well as the needs of its purchasers.

One participant noted that reliability and availability of mining equipment are key factors to its usefulness. He suggested that it might be interesting to finance development of a state-of-the-art piece of equipment using, for example, high-tech hardening techniques for alloys, and any other available advances. It would then be possible to evaluate whether the resulting improvements in reliability and performance might be cost-effective in commercial production.

5. Basic R&D and Long-Term Applied R&D

Participants generally agreed that basic and long-term applied R&D in mineral areas are seriously neglected in Canada. Universities, which are the logical location for long-term research, have focused on short-term and medium-term R&D following industrial objectives. This has been necessary, it was stated, in order to obtain funding. There is virtually no source of funding in Canada at present that can be tapped to build up a base of expertise in long-term mineral-related R&D. In spite of this short-term focus, some university researchers noted, there has been relatively little interest on the part of Canadian companies in the results of Canadian university R&D. Greater interest, in the form of enquiries, requests for reprints, and consulting work, has been shown by companies outside Canada, particularly in the USA, South Africa and Chile.

The example of the Colorado School of Mines (CSM) was cited, where industry contributes funding, participates in setting the research agenda, and cooperates closely in the research. The result has been a surprising 70-30 split of R&D effort, with fully 70 percent of CSM's attention going to long-term R&D. Someone, it was stressed, has to ask basic questions about what will mining or advanced technology look like in 5 years, or 10. In a more speculative vein, it is also necessary to have someone sit down and reinvent mining, starting from first principles and making no assumptions about the necessity for using existing methods and approaches.

It was pointed out that many of the discontinuous advances that have fostered rapid-growth industries in high tech and in the aerospace industry were initiated within universities. This can happen only when there is a combination of basic R&D expertise plus communication and entreneurial spirit to move ideas out of the laboratory and into application and commercialization.

It was also noted that universities should by no means focus exclusively on long-term R&D. A mix of long, medium, and short-term interests is essential to keeping the innovative process operating.

Participants noted that funding priorities for government support of R&D in universities are at present determined by bureaucrats operating within the political process. However, governments of necessity have a short-term and applied orientation. In order to

promote awareness of the role of basic and long-term applied R&D, there is a need for an increased involvement of academics in the establishment of priorities, in addition to their present role on some of the bodies which allocate the individual grants. Industry also needs to become more aware of the benefits of basic and long-term R&D, and to be involved in the policy process of setting priorities.

It was suggested the present neglect of basic R&D would be eased if basic funding were given its own vehicle, clearly separated from applied funding in government support programs such as NSERC operating grants.

Selling Technology to the Competition

The discussions of the need for government/university/industry cooperation in the development of new technologies raised a very interesting and fundamental question: to what extent should the results of R&D go into immediate sales of technology to the competition?

It was felt that there is still considerable opposition to the idea of selling technology abroad that will contribute to the competitive position of other mineral producers. However, there was a significant degree of support among the participants for the opposite view, namely that there is more to be gained by Canadian mining firms from being open with innovations than from being secretive. Among the reasons offered by participants as to why Canadian mining companies should not be concerned about possible negative effects of selling Canadian technology abroad were the following:

- companies working on innovation have found that openness rather than secrecy facilitates the rate of development of new technologies;

- increasing the speed with which innovations are applied can provide such financial advantages to a company that any ensuing advantage given to competitors because of openness is worth it;

- in most developing countries, the basic problems revolve around more employment, rather than labour reduction which is a fundamental goal of most Canadian innovations;

- capital-intensity-enhancing innovations, the principal sort sought in Canada will not be cheap, and therefore may not be attractive to third world competitors;

- innovations suitable for introduction in Canadian mines and processing may in some cases be too sophisticated for application in developing countries;

- payback from technology sales, domestic or export, helps to fuel further innovation;

- rate of technology change is rapid and increasing, so the only way to stay ahead is to be the innovator, and to keep innovating;

- whether or not Canada sells its technology abroad, other countries such as Finland, Sweden and Germany will continue to sell technology. Canada might as well sell technology too, stay a leader, and share in the benefits of technological leadership;

- the process of selling and setting up Canadian technology abroad is a learning experience in itself that can make a positive contribution to Canadian innovative efforts;

- the advantages of openness are demonstrated by the experience of Outokumpu, which has become a world leader in the industry with a relatively small (and soon to be depleted) base of domestic mining, by pursuing a very active program of developing and exporting equipment and technology;

- finally, it may help to open the door to foreign technology. Canadian industry needs such access urgently; it needs to identify useful emerging technologies early and then to use them, along with the agreed-upon home grown technology.

Responding to the Problems and Needs

Cooperation

1. The Players

In the course of small group discussions a broad range of interested parties was identified, groups and organ-

izations that must be considered in the process of seeking cooperation for a more effective innovation effort in the mineral industry. These included:

- the producing sector - exploration, mining, and smelting and refining companies, from the smallest junior mining firms to the largest integrated multinational firms; industry associations and organizations; unions and labour; consultants; contractors; equipment manufacturers;

- the government bodies and agencies - federally, EMR/CANMET, MOSST, DRIE, NRC, NSERC, Environment, DIAND, interdepartmental committees, and political forums such as parliamentary committees; provincially, departments of mines, labour, environment, and health, provincial research organizations, and interprovincial committees;

- universities, colleges, and technical schools;

- special interest groups such as environmentalists, resource communities, scientific and professional organizations, etc;

- international bodies of industry, government, or combinations of both.

It was noted that, in any cooperative effort, there must be some winners and some losers, even where there are overall gains to be realized. There will of necessity be shifts in authority, jurisdiction, responsibility, and funding sources and allocation. Some participants expressed serious doubt that the interested parties are adequately motivated to make the compromises that will be necessary to achieve a significant degree of cooperation in sharing the costs and the benefits of R&D and innovation.

2. Cooperation For Coordination of Effort

There was support at the seminar for the view that there is a need for a formal, focused effort at coordinating expenditures and activities in mineral-related R&D. In the MAC presentation and subsequent discussions, it was recommended that such an effort should begin with establishing a coordinating body which would work toward focusing the R&D expendi-

tures of both government and industry on areas of agreed need and opportunity. It was suggested that existing centres of strength within universities could become the nucleus for such focused funding and efforts, reinforced by the facilities of government laboratories, and drawing on the expertise in the same areas in other universities and in industry.

The initiative to establish a coordinating body should be industry-driven, it was agreed, but it should enlist the cooperation of all interested parties. The body should be small, and drawn from senior levels of the industry, of government, and of universities. It should keep 2-way communication open with all interested parties.

There was support for the view that decisions on funding cannot wait for consensus from all companies or all government or their agencies, in terms of either participation or share of support. Instead, decisions should go ahead on an ad hoc basis with whatever funds become available, much as the individual mineral development agreements between the federal government and the provinces have gone ahead, one by one.

3. Cooperation To Facilitate Innovation

A second form of cooperation was identified by participants throughout the discussions: cooperation between organizations and (especially) between individuals, in the communication of industry needs and of R&D and innovation developments to meet these needs. This cooperation will not take place in task forces or formal committees, it was noted, but on a person-to-person level. The substance of the communications will be scientific and technical. These activities cannot be confined to centres of strength, although they may use such centres as meeting grounds and bases of operations. They must be decentralized and widespread, involving researchers in all university, government and industry facilities as well as operating personnel affected by and in need of the resulting innovations.

The example of the Advanced Material Technology Unit (AMTU) at Queen's was cited as one such model of this sort of communication and cooperation. Although based at Queen's, it has no infrastructure or facilities of its own, and involves a large group of individuals with common interests from many different

organizations and locations.[1] To some extent, this sort of activity is presently carried in meetings of professional and technical organizations, such as the CIM at its branch, district, and division meetings, and among more specialized bodies. However, there is still a need for greater interaction, discussion, feedback, and generation of new ideas and collaboration among the interested parties, as well as wider distribution of papers presented.

Division of R&D Labour - Short, Medium and Long Term

Participants generally agreed that there should not be hard and fast divisions between sectors (i.e. universities, industry and government) in terms of length of R&D focus. Instead, the need for cooperation and communication dictates that there be considerable overlap, both in length of focus and in the pursuit of individual R&D projects.

Nevertheless, there was agreement that universities are the only place that can successfully pursue basic research and long-term applied research, and that this should form the bulk of university R&D activities related to the mineral industry. At Colorado School of Mines, as mentioned above, long-term research constitutes 70 percent of the total effort, a much higher level than in Canadian university departments. CSM considers long-term R&D to focus on advances that may take as long as 15 years or more to realize.

Industry and government, on the other hand, cannot focus beyond 4 years, it was suggested. Much of industry's R&D is really process modification, and has a time frame more like 6 months. Industry, it was agreed, should concentrate in-house on short-term R&D, with some medium-term efforts in firms large enough to support it. Government facilities should also concentrate on short to medium term activities, aimed at specific industry needs. Both, however, should support funding for longer-term projects.

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[1] One project of this group, involving cooperation between Almax Industries, Queen's Department of Physics and CANMET, is one of five finalists in the 1986 Canada Awards for Excellence, technology transfer category. The project, which involves ceramics technologies, has contributed to a sales increase from $0.5 million to $4 million and a doubling in the number of employees, from 40 to 80, over the period 1982-86.

Industry's Role

While stressing the need for cooperation, participants also singled out special roles for industry, universities and governments in enhancing technological innovation. Among the tasks identified as the responsibility of industry were the following.

1. In House:

   - develop a positive and supportive management attitude toward R&D and innovation.

   - communicate the observed benefits of R&D to others, inside the company and in other companies.

   - include in the goals of innovation: productivity improvement; product quality improvement; increased flexibility in production, tying it more closely to demand, in terms of production volume and other characteristics; and improved health, safety, and environmental protection.

   - initiate active programs of intelligence-gathering in technologies and in changing trends in materials demand.

   - support market development activities.

2. Outside the Firm

   - use consultants to expand the available base of knowledge and interdisciplinary skills.

   - cooperate with universities in funding and focusing applied R&D, and in following up research projects.

   - integrate forward into high tech and equipment firms that can assist in innovation activities.

3. In Joint Ventures

   - pool resources among companies for more effective R&D activities, as HDRK is attempting to do.

- larger firms can cooperate with smaller firms, making facilities and results available and sharing costs, as for example Falconbridge does with some of its subsidiaries.

- join in joint ventures in applied short- and medium-term research with university and government researchers.

- establish joint ventures or organizations on a commodity basis where needed for marketing or product development studies, and on a wider basis for other technical studies related to production, such as ground control, communication, automation, etc.

- establish joint ventures with equipment manufacturers, to share in the risks of development and to improve the linkages between the innovators and the advisers.

4. Industry-Wide

- provide the drive to increase and focus government and industry funding for R&D.

- communicate the benefits of R&D and promote a widespread positive management attitude towards innovation.

- help to facilitate the 2-way flow of technical information between innovators and producers.

Universities' Role

Participants suggested a number of ways in which university researchers could make their contributions to innovation more effective. These included:

- putting pressure on funding sources for support for basic and long-term R&D;

- putting pressure on NSERC for more attention to mining and mineral-related applied R&D;

- promoting themselves to industry, seeking both financial support and direct cooperation in short- and medium-term projects;

- engaging in consulting activities, but ensuring that younger staff members as well as senior ones get involved;

- using outside facilities where available (e.g. industry and government labs) to supplement their own resources and to expand the students' range of experience;

- encouraging and seeking out support for multidisciplinary studies, where appropriate, breaking down traditional barriers between disciplines and academic departments, and between universities.

Governments' Role

Governments were seen by participants to have important responsibilities in the three major areas: funding, in-house R&D, and communications or technology transfer.

1. Funding

   - provincial governments now fund the basic facilities and salaries for universities;

   - federal funding now supports much of the R&D in universities, plus some in industry;

   - a significant increase is needed in the level of funding for basic and long-term applied R&D (as opposed to short-term applied projects);

   - NSERC should establish a committee (or committees) specifically for mining and mineral-related proposals;

   - a significant increase is needed in the level of funding allocated to mining R&D;

   - an effort should be made to involve industry directly, both in providing funds for R&D and innovation, and in the allocation of such funds among projects and researchers;

   - federal funding and other programs for oil and gas and for mining should be separated;

- government can assist (as it does already for several organizations) industry organizations for technology activities with funding and/or infrastructure support.

2. In-House R&D

- government R&D organizations such as CANMET and provincial research agencies should communicate better with operating and R&D groups in industry, in order to promote increased industry collaboration and the transfer of innovation resulting from government R&D. (A clear correlation appeared between negative and at times very critical comments about CANMET from industry representatives and lack of familiarity, particularly recent communication, with CANMET's activities.);

- provincial and federal research facilities should conduct medium to long-term R&D aimed at assisting the industry in meeting its obligations with regard to health, safety, and environmental protection;

- CANMET's national facilities are very well equipped, and should be made available for use by industry and university researchers, for example during sabbaticals or as part of jointly-run graduate or post doctoral research programs. This would increase the resources available to researchers, improve communications, improve the rate of use of the equipment in the face of possible cutbacks in CANMET funding and staff, and provide greater flexibility in terms of the expertise of researchers using the facilities.

3. Technology Transfer

Government agencies, particularly but not exclusively CANMET, are well placed, participants suggested, to assist with technology transfer and communication activities including:

- technology transfer to smaller firms lacking R&D capabilities;

- international technology transfer activities;

- technology data bases (building for example on MINTEC and MINPROC);

- technology transfer activities by personal contact, by sponsoring or participating in meetings and workshops, and through publications.

A First Step - the MAC Technology Initiative

Favourably Received

Participants generally agreed with the broad thrust of the MAC thesis, as presented by Walter Curlook, that there is an urgent need for strong leadership in initiating national strategic planning to set priorities for R&D and technology innovation funding and activities, on the basis of the needs and opportunities facing the Canadian mineral industry. It was also generally agreed that the initiative should arise from the industry itself, and that the MAC's initiative is both appropriate and timely. At the same time, universities and governments also have essential roles to play in the strategic planning activities.

Comments on the MAC initiative can be described under five categories:

- general comments on the approach and its timeliness;
- obstacles to success;
- suggestions for the top level, the national advisory board (CIAMMT);
- suggestions for the centres of strength;
- suggestions concerning funding.

General Comments

1. **Timing:** participants felt that the timing is right for the MAC initiative, for a variety of reasons over and above the obvious needs of the industry to maintain its competitive position. For example, some pointed out that there is a "window of opportunity" at present in dealing with the federal government, which is now in a rather fluid state for technology funding, and looking at possible changes in policies, programs, structures, processes, focus, and funding levels for R&D and technology in general.

In addition, in view of the recent moves in the USA towards the establishment of centres of strength in mining technology, Canada must move quickly in order to compete

with the U.S. centres on a variety of fronts, including obtaining funding from mining multinationals, recruitment of R&D staff, and leadership in specific areas of expertise.

Participants felt that MAC should not wait for consensus in establishing its proposed board and in supporting centres of strength. Instead, it should go ahead with any groups willing to join in at this time, while leaving the door open and continuing to encourage new entrants at the advisory level, as researchers and end-users, and as sources of funding.

2. **Flexibility:** expanding on the last point above, it was emphasized that the proposed structures of boards and centres at all levels should be flexible, permitting not only new entrants in all aspects, but also new research directions, focus of activities, goals, lines of communication, and approaches to funding.

3. **Active Support:** participants were advised that no one should sit back and let the MAC take full responsibility for the success or failure of the technology initiative. Its success will depend on active participation within all organizations connected with the mineral sector. Individuals throughout the sector will be needed to perform a proselytizing and facilitating role, within companies, government and university departments, through professional and scientific organizations and meetings, and through personal contacts. Only with a broadly-based and concerted effort can the necessary momentum be established and the traditional barriers to communication and technology transfer be removed.

Obstacles

Obstacles to innovation and technology transfer were identified in most of the presentations, and elaborated upon throughout the discussions. Some were of particular relevance to the MAC initiative and are repeated here.

1. **Disciplinary barriers:** within and between university departments, these barriers constrain attempts at interdisciplinary research, which is an essential feature of many of the new areas of technology.

2. **Size of Mining Departments:** the suboptimal or barely optimal size of most mining (and metallurgy) departments in Canadian universities makes any enhancement of one depart-

ment (for example, to create new chairs or centres of strength) appear to be a threat to the viability of others. As a result, there has been counterproductive competition rather than cooperation between universities.

3. **Role of CANMET:** the variety of views on CANMET's present functioning and what its future role should be, as indicated in several of the presentations and in a number of published comments and reports, will complicate the achievement of a consensus on means for its rapid integration into the technology initiative, at all three levels of activity (advisory, R&D performance, and funding).

4. **Benefits:** the distribution of the benefits arising from technological innovations funded by a consortium of government and industry sources will be a contentious matter, one that requires careful advance consideration.

5. **Government Jurisdiction:** the division of responsibility for R&D and technology in general, and for the mineral sector and its economic, social and environmental impact in particular, among a wide variety of federal and provincial departments and agencies greatly complicates the task of giving adequate representation to all interested parties at the advisory level.

National Advisory Board (CIAMMT)

1. **Membership:** the advisory board should, as far as possible, represent all the interested parties, including industry (recognizing the different technology needs of the various stages of production and various commodities), universities, federal and provincial government departments with mineral industry and R&D funding responsibilities, and other interests including consultants, equipment manufacturers etc. There is a need, it was noted, to incorporate the concept of the interdependence of R&D sponsors and end users at this level. At the same time, it was warned that the size of the body should be restricted sufficiently so it can in fact make decisions or reach a consensus.

2. **Role:** the Board's role was seen by most to be limited to an advisory capacity: identifying short and long-term needs and the foci for funding and research programs; evaluating ongoing programs; and advising on the level and allocation of funding. Although it was not anticipated that the Board would be a funding agency itself, its opinions

would carry a great deal of weight with the actual funding bodies, both in government and in industry. Other participants were concerned that such an advisory-only role would undermine the board's ability to achieve significant results.

3. **Structure:** the Board, it was stressed by some, should be essentially a committee of individuals representing the various constituencies. Beyond a small secretariat, probably best provided within EMR, it should have no budget, no bureaucracy, and no building.

Centres of Strength

1. **Location:** the centres should all be autonomous bodies located within existing university departments or consortia of departments, building on existing strengths in terms of research facilities, and in terms of the number, interests, and capabilities of researchers. For this reason, some participants argued, the term "centre of strength" is preferable to "centre of excellence", since the latter term does not necessarily carry the connotation of building on existing strengths.

The centres should be considered national facilities, rather than the exclusive property or concern of the host university. They should stress collaboration in teaching, degree granting, and research with other universities, and collaboration in research, development, and commercialization of technology with industry and government researchers and with equipment manufacturers. Communication should not be limited to Canada, and should be two-way, flowing freely between the researchers and the end users.

2. **Subject Matter:** the MAC initiative proposed centres of strength based on areas of subject matter. Participants offered suggestions for changes and additions to the MAC list, which was expanded to include the following technical areas (in no particular order of importance - the sequence of initiation of the various centres would be determined by the Board).

- rock mechanics (which, it was suggested, should be considered in a broader context, such as rock physics);
- mine automation and robotics;
- metals, alloys and new materials;

- mineralogy and mineral dressing;
- exploration techniques and technology, including geophysics, geochemistry, and remote sensing;
- coal research;
- product and market development;
- health, safety, and environmental studies.

It was noted that centres' responsibilities should not cease with innovation but should carry forward into the incorporation of new technologies into end-use applications.

3. **Short-term/Long-term Balance:** there was some concern expressed that the subject-matter focus of centres of strength would perpetuate the present over-emphasis on short-term activities. It was noted that none of the centres as defined has a mandate to stand back and reinvent mineral extraction and processing techniques from first principles. In general, it was felt that there should be some industry and government involvement in long-term R&D within the centres, but that their collaboration should focus chiefly on short to medium-term R&D, demonstration, and commercialization.

Funding

1. **Allocation:** participants generally agreed that funding allocation should be guided by but not actually the responsibility of the proposed advisory board. Allocation should continue to be made by the bodies providing the funds, but much greater effort should be made to seek the advice of the researchers and the end-users.

2. **Sources:** it was assumed that governments would continue to be a major source of funding for R&D and technological innovation activities for the mineral sector. Participants also stressed, however, that industry should play a much larger role in funding. Not only would this increase the overall level of funds available, and provide rationale for continuing government financial support, it was felt it would also ensure increased commitment on the part of the industry to direct and to exploit the results of R&D.

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Appendix II Program of the Seminar

16TH CRS POLICY DISCUSSION SEMINAR

TECHNOLOGY POLICIES IN THE MINERAL INDUSTRY

Monday, April 7, 1986

7:00 p.m. **The Technical Challenge Facing the Canadian Mineral Industry**
Roy Woodbridge, President, Canadian Advanced Technology Association

Tuesday, April 8, 1986

9:00 a.m. **Opportunities for Technological Innovation in the Mineral Industry**
Margot Wojciechowski, Assistant Director, CRS

10:00 a.m. **The Role of R & D in Canadian Mining Companies**
Frank Pickard, V.P. Metallurgy and Engineering, Falconbridge Ltd.

11:00 a.m. **Barriers to Innovation within the Mining Industry**
Donna M. Bevelander, Bevelander and Company

1:00 p.m. **Future Directions for CANMET: A View from the Steel Industry**
John Hood, Research Manager, Product Development, Stelco Limited

Future Directions for CANMET: the CANMET View
W.G. Jeffery, Director General and Justyna Kuryllowicz, Director, Office of Technology Transfer, CANMET

Cooperation between CANMET and Industry
Peter Richardson, Associate Professor, Queen's School of Business

4:00 p.m. **Cooperation in the Nickel Industry**
Hans Schade, President, Nickel Development Institute

8:00 p.m. **The MAC Technology Initiative**
Walter Curlook, Executive Vice President, Inco Ltd.

Wednesday, April 9, 1986

8:30 a.m. PANEL DISCUSSION: **The Role of Other Institutions in New Technology**
Michael Sayer, Advanced Materials Technology Unit and Physics Department, Queen's University

Gerry Hatch, President, Hatch Associates Ltd.

Duncan W. Hutchison, Sales Manager, Continuous Mining Systems Ltd.

A. Molinari, President, Outokumpu Equipment Canada Ltd.

3:00 p.m. Group Discussions and Plenary Session

4:00 p.m. Concluding Remarks

THE AUTHORS

Donna M. Bevelander has a B.Sc. from the University of Toronto, and has done graduate studies at the University of British Columbia and Memorial University (CAD/CAM Engineering). She also holds a Robotics Certificate from the American Institute of Robotics. Her work experience includes survey development and administration, and technology transfer and policy studies. Ms. Bevelander established her own firm, Bevelander and Company, in 1982 and provides services in project management, research, policy and technology consulting, and communications development.

Walter Curlook graduated from the University of Toronto, where he received a B.Sc. and a Ph.D. in metallurgy. He joined Inco in 1954 as a research metallurgist, and in 1974 was named Vice President of Inco Ltd., in charge of corporate planning. He has since served as Senior Vice President of Inco, and President and Chief Executive Officer of Inco Metals. Dr. Curlook's present position is Executive Vice President of Inco Limited. He has also held many positions in mining industry organizations, including that of President of both the Ontario Mining Association and the Mining Association of Canada.

Gerald G. Hatch has a B.Eng. in metallurgy from McGill University, and a Sc.D. in process metallurgy from the Massachusetts Institute of Technology. Following employment in mineral processing research and management for Shawinigan Water and Power and Quebec Iron and Titanium, in 1958 he established Hatch Associates, and serves as its president. Hatch Associates provides engineering services related to process engineering, design, and project management, and consultation on acquisitions, evaluations, project development, and direction of R&D programs.

John E. Hood has a B.Sc. in metallurgy and an M.Sc. in engineering from the University of Aston in Birmingham. He has worked for Stelco in a number of capacities, including R&D related to development of an Arctic pipeline and R&D in flat and tubular products. He is presently Research Manager - Fabrication and Products, at Stelco, and is also chairman of the subcommittee on Materials and Utilization of CANMET's National Advisory Committee on Mining and Metallurgical Research.

Duncan W. Hutchison graduated from Queen's University with a B.Sc. in mining. His employment experience includes underground supervision with Denison Mines Ltd., supervision and development of new underground mining equipment for Joy Manufacturing, and regional manager for Jarvis Clark Co. Ltd. He is presently Sales Manager for Continuous Mining Systems Ltd.

W.G. Jeffery obtained a B.Sc. in mining engieering and an M.Sc. in economic geology at the University of Leeds. He then worked in Africa in diamond mining and the asbestos industry. Postgraduate studies at McGill led to his Ph.D. in 1959. In Canada he has worked with mining companies, with the B.C. government, as a consultant in external aid, and in various positions with EMR in the federal government. Presently Dr. Jeffery is Director-General of the Canada Centre for Mineral and Energy Technology.

Justyna Kuryllowicz graduated from McGill University with a B.Eng. in mining engineering. Prior to joining the federal government, she worked for Inco Ltd. in Manitoba, Gilbraltar Mines in British Columbia, and Algoma Ore in Ontario. Miss Kuryllowicz is currently the Director, Office of Technology Transfer, at the Canada Centre for Mineral and Energy Technology.

Adrian Molinari joined Sala International in Toronto in 1971, with responsibility for marketing equipment developed by Outokumpu of Finland, to the Canadian mining industry. In 1975 he established Outokumpu's first subsidiary outside Finland, Outokumpu Equipment Canada Ltd., to develop Canadian markets for technology and equipment developed by the parent company. Recently Mr. Molinari has been appointed President of Outokumpu Mines Ltd., a new Canadian subsidiary for Outokumpu, formed to invest in Canadian mining operations through exploration and acquisitions.

Franklin G.T. Pickard graduated from Queen's University, and in 1957 began his career at Falconbridge in the Sudbury operations. His positions with Falconbridge have included Mill Superintendent, Chief Metallurgical Engineer, and Director of Metallurgy and Engineering. Since 1982 Mr. Pickard has been Vice President, Metallurgy and Engineering. He is also President of Lakefield Research Division of Falconbridge, and an officer or director of numerous subsidiaries.

Peter Richardson has a B.Sc. in engineering from Leeds University, and later worked in the steel industry. In 1975 he obtained a Ph.D. in business administration from the University of Western Ontario. He has taught business administration at Western, the Iran Centre for Management Studies, and Queen's University, where he is associate professor in the School of Business. Dr. Richardson has also acted as consultant in the areas of cost management and corporate strategy with Noranda, Falconbridge, Alcan, and Kidd Creek Mines. He is also a faculty associate of the Centre for Resource Studies.

Michael Sayer has a B.Sc. from the University of Birmingham and a Ph.D. from the University of Hull, both in solid state physics. He has held teaching and research positions at the University of British Columbia, Trent University, the University of Sheffield, and Queen's University, where he is now professor in the Department of Physics, Associate Dean (Research) in the Faculty of Applied Science, and a founder of the Advanced Materials Technology Unit. Dr. Sayer has a wide range of consulting and contracting experience with Canadian and international organizations including Atomic Energy of Canada, Alcan, Almax Industries, Luxel Corporation, and L'Octet's France/Canada collaborative research program in high temperature ceramics.

Johannes Schade majored in thermodynamics and iron and steel technology at Clausthal University. He was with Union Carbide in Europe, where he served as marketing director of the Ferro-Alloy Division, before joining Inco as Managing Director of International Nickel Deutschland and later as Regional Marketing Manager of Inco Europe Ltd. In 1977 he moved to Canada with Inco, where he was Senior Vice President with responsibility for primary metals marketing. In 1984 he was elected president of the newly-founded Nickel Development Institute, an industry organization for market research and development.

Margot Wojciechowski has a B.A. in Political Science and Economics from the University of Toronto (1958) and an M.A. in Political Studies from Queen's University (1970). Her professional experience includes three years as an economist with the Dominion Bureau of Statistics, and several research positions in the field of public administration. She is now assistant director of the Centre for Resource Studies at Kingston, and author and editor of an extensive list of publications in mineral policy and mineral economics.

Roy Woodbridge studied at Carleton University, where he received a B.A. in political science and economics, a Graduate Diploma in public administration, and an M.A. in international relations. He worked for the federal government from 1966 to 1983, in a variety of departments and agencies including the Canadian International Development Agency in East Africa, Energy Mines and Resources in the Mineral Policy Sector, and Industry Trade and Commerce, where he was Chief of Policy and Analysis in the Electrical and Electronics Division. In 1983 he moved to the Mining Association of Canada as Director of Mineral Economics, and in 1986 he joined the Canadian Advanced Technology Association as its President.

THE CENTRE FOR RESOURCE STUDIES

The Centre for Resource Studies (CRS) was established in 1973, under the sponsorship of Queen's University, the federal Department of Energy, Mines and Resources, and The Mining Association of Canada, to carry out a program of research and publication on mineral policy issues.

The Centre provides opportunities for multidisciplinary research in resource studies at Canadian universities, furnishes reliable information on matters related to mineral resource policy, and promotes closer liaison between government, industry and other concerned groups. The research program is carried out both at the Centre and by means of contracts with qualified investigators, usually at Canadian universities. Small exploratory studies are also funded, through a system of grants-in-aid of research. CRS Seminars involve representatives from governments, industry, universities, labour, and other interested groups in working sessions on issues of current concern. Through this program of research and seminars, and the resulting publications, the Centre contributes to informed discussions and a better understanding of significant issues.

The Centre is governed by a board of directors which establishes general policy and priorities for research. The board has sixteen members, appointed by Queen's University, The Mining Association of Canada, and the federal government. Guidance on the research program, together with discussion of policy issues and other matters, is provided by the Advisory Council. This body comprises all researchers associated with the Centre, together with members appointed from such groups as governments, industry, labour, and other interests. A Research Advisory Committee aids in the development of projects and the selection of research proposals. The executive director and staff are responsible for the work of the Centre within this framework.

Most of the funding for the Centre's activities is provided by two of the sponsors, EMR and MAC. In addition, the Centre accepts contracts from other organizations interested in mineral policy research.

The Centre welcomes comments on its publications, proposals for research projects or for publication, or enquiries about any aspect of its work. For further information, contact:

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CRS PUBLICATIONS

Monographs and Collections

Conflict and its Resolution in the Administration of Mineral Resources in Canada, by R.M. Burns; 61 pages, 11 tables. Published 1976.

The Impact of the Mining Industries on the Canadian Economy, by R.W. Boadway and J.M. Treddenick; 116 pages, 15 tables. Published 1977.

The Transportation Impact of the Canadian Mining Industry, by A.I. Wallace; 154 pages, 17 tables. Published 1977.

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